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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum No. 33-296

Semiannual Review of

Research and Advanced Development

January 1, 1966 to June 30, 1966

Volume I. Supporting Research and Technology for the Office of Space Sciences and Applications, National Aeronautics and Space Administration

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

July 31, 1966

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Research and Advanced Development

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

July 31, 1966

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National Aeronautics & Space Administration

NOTE

This document is designed to serve the needs of personnel at JPL, NASA Headquarters, and NASA Centers. It is not to be distributed outside of JPL or NASA without the specific approval of the JPL Office of Research and Advanced Development.

PREFACE

This document has been prepared under the direction of the Office of Research and Advanced Development of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California.

The Semiannual Review of Research and Advanced Development is published in three volumes directed to the appropriate NASA funding offices:

Volume I	Supporting Research and Technology for the Office of Space Sciences and Applications
Volume II	Supporting Research and Technology for the Office of Advanced Research and Technology
Volume III	Supporting Research and Technology for the Office of Tracking and Data Acquisition (New Systems and Spacecraft Subsystems)

This issue reports progress for the period of January 1 to June 30, 1966, Fiscal Year 1966. Preceding issues were published as follows:

Fiscal Year	Calendar Period Covered	JPL Technical Memorandum No.	Publication Date
1965	January 1 to June 30, 1965	33-243	August 15, 1965
1966	July 1 to December 31, 1965	33-272	January 31, 1966

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PART A. LUNAR AND PLANETARY EXPLORATION

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PART A. (Cont'd)

PART A. (Cont'd)

PART A. (Cont'd)

Spacecraft and Capsule Equipment Development (186-68) (Cont'd)

PART A. (Cont'd)

Spacecraft and Capsule Equipment Development (186-68) (Cont'd)

PART A. (Cont'd)

PART B. PHYSICS AND ASTRONOMY

PART B. (Cont'd)

PART C. BIOSCIENCE

PART C. (Cont'd)

PART D. MANNED SPACE SCIENCES

INTRODUCTION

This volume contains a review of all supporting research and technology in progress at the Jet Propulsion Laboratory during the period January 1 to June 30, 1966, under direction of the JPL Office of Research and Advanced Development, for the NASA Office of Space Sciences and Applications.

The work units are arranged in numerical sequence by NASA code in each subject section. To locate a desired unit, refer to the Table of Contents under the appropriate subject heading.

JPL research and advanced development results published during FY 1966 as JPL documents and in the open literature are listed under each work unit.

Part A
Lunar and Planetary Exploration

SCIENCE (185)

INSTRUMENTATION (185-24)
PULSE HEIGHT ANALYZER DEVELOPMENT
NASA Work Unit 185-24-05-04-55
JPL 383-32601-2-3230
W. J. Schneider

OBJECTIVE

The long-range objective of this work unit is the design and development of a general purpose pulse height analyzer for space applications. The proposed instrument will possess sufficient versatility to lend itself to application by any and all of the presently conceived space radiation experiments that require either pulse height analysis or multiscaler capability. A shorter range objective is to obtain an engineering model analyzer before the end of FY 1967.

PROGRESS

The system design of the analyzer has been completed during the report period. The design incorporated features for gamma ray spectrometry, neutron activation analysis, multiparameter analysis, and multiscaler time analysis. A design review was conducted and the design requirements and intended mechanization were presented by the design contractor. As a result of the design review discussion with the NASA-appointed Neutron Analysis Working Group and the interested scientists, a request was made to the contractor for certain minor modifications in the design specification. The minor modifications were incorporated to ascertain the acceptability of the analyzer to their proposed experiments.

Detailed electrical design has been initiated. The designs of the various circuits of the analog-to-digital converter have been completed. Tests were performed on the breadboard circuits to determine the circuit gain stability. A 3- x 3-in. NaI radiation detector, phototube, and high-voltage supply were purchased in preparation for these tests.

The specifications for a 512- x 18-bit memory unit for the analyzer have been established. The memory will contain an address register and a data register, both with parallel input and output lines. The electronics will be responsive to set, reset, and scaler advance signals and read and write pulses. The design and construction of the memory unit are to be done by the contractor's Advanced Memory Product Division. Arrangement for a design review has been made with the objective of reviewing the memory design prior to the actual construction.

To guide the fabrication of the electronics toward the anticipated flight prototype design, sample quantities of the JPL integrated circuit stick modules, wire-con headers, and Mariner-type subchassis have been introduced to the contractor, and the contractor has agreed to use the JPL construction in the packaging of the engineering model of the analyzer. The engineering model will thus have a construction form approaching that of a flight prototype. Procurement of sufficient modules for fabrication of one complete analyzer is in process. These modules will be furnished to the contractor during the fabrication phase of the contract.

Future work will include: (1) completing the design and development of the engineering model of the analyzer, (2) conducting final review of the analyzer electrical design, and (3) initiating the engineering model fabrication phase of the design contract and guide the contractor toward the packaging concepts chosen for the flight prototype unit.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. Despain, L. G., Pulse Height Analyzer, SPS 37-34, Vol. IV, pp. 181-182, August 31, 1965.

2. Schneider, W. J., Precision Testing of Pulse Height Analysis, SPS 37-36, Vol. IV, pp. 202-204, December 31, 1965.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

SPACE CHEMISTRY (185-37)
LUNAR AND PLANETARY X-RAY DIFFRACTION

NASA Work Unit 185-37-20-02-55
JPL 383-30201-2-3250

J. A. Dunne

OBJECTIVE

The lunar and planetary X-ray diffraction program has as its principal objective the development of instrumentation and instrumental concepts capable of conducting mineral phase analysis on the surfaces of the Moon and Mars. X-ray diffraction and supporting fluorescence techniques form the overall experimental framework of the effort.

FIELD TEST SUPPORT

During the report period, an improved field test diffraction system was prepared at JPL for the U. S. Geological Survey Astrogeology Branch, Flagstaff, Arizona. The system, consisting of a lunar-type diffractometer and associated analyzing electronics and power supplies, was operated successfully in a field test field in the Hopi Buttes area near Winslow, Arizona, May 9 through 20, 1966. Around 125 complete diffraction diagrams were obtained and analyzed in the course of the field test. The purpose of this and similar field tests is the evaluation of the utility of certain analytical instrumentation to geologic field reconnaissance missions in proposed post-Apollo lunar exploration programs.

CRYSTAL MONOCHROMATOR

Preliminary evaluation of the advantages of crystal monochromatization of the diffracted beam is expected to be complete by the end of the report period. As a result of the severely optimized nature of the lunar X-ray diffractometer optical design, it has been found that it is not possible to dispense completely with detector-side Soller slit horizontal divergence limiters when employing the monochromator, as is the case in conventional lab instruments. As a result, the performance of the miniaturized monochromator built for the lunar-type instrument does not equal that obtained in ordinary laboratory practice. It has been tentatively concluded from the test results to date that the advantages of a crystal monochromator do not offset the loss in intensity and resolution attendant upon its uses in a lunar-type diffractometer. Pulse amplitude distributions obtained on the α Fe (110) peak with and without monochromatization are given in Fig. 1.

ANCILLARY X-RAY FLUORESCENCE ANALYSIS INSTRUMENTATION

The most significant problem encountered in applying X-ray fluorescence techniques to diffractometer sample analysis is the very low excitation efficiency that can be expected. This means, of course, that flux collection efficiency must be high, a requirement which rules out the use of optical (crystal) dispersion. Classical nondispersive techniques are, on the other hand, severely limited in resolving power, and present difficult engineering problems in stability control. An alternative nondispersive method is that of balanced filter energy resolution which takes advantage of elemental absorption discontinuities to isolate the wavelength of interest from the other components of a fluorescence spectrum. Figure 2 shows the positions in wavelength of the pass filter and absorbing filter absorption edges with respect to

the line of interest. For a suitable balanced pair of filters, any difference observed between intensity readings taken through the pass and absorption filters can be taken as a measure of the amplitude of the line of interest in the fluorescence spectrum. Figure 3 shows the resolution obtainable for 1/2 wt % aluminum in silicon using appropriate balanced filters. The results of initial investigations in this area were sufficiently promising that a simple breadboard apparatus will be constructed during FY 1967 for more comprehensive testing. It is not clear at this writing, however, whether balanced filter methods will prove preferable to electronic dispersion techniques, since the flux collection efficiency required in the lunar-type diffractometer geometry, although known to be high, has not yet been established with sufficient precision.

SCANNING MODES

Data have been collected using a laboratory instrument capable of scanning in angular steps of various sizes which will provide tradeoff information valuable in choosing the optimum scan mode to be employed in a given flight experiment, consistent with available power. Upon completion of data reduction and analysis, it will be possible to specify important performance parameters (minimum detectable limit of individual crystalline phases in the sample, resolving power, precision of peak amplitude measurements, etc.) as a function of step-scan increment in the range 0.01 to 0.05°2θ. Figure 4 shows the minimum detectable limit calculated for the Fe_2O_3 (104) peak in a quartz matrix as a function of step increment; Fig. 5 shows scans of that line in a sample consisting of 1% Fe_2O_3 in quartz at 0.01 and 0.05° 2θ step increments.

Figure 6 presents a program milestone summary for FY 1966. The flight breadboard system shown in the chart should have included an electronically sensed and programmable digital shaft encoding subsystem, which would have allowed automatic flight experiment simulation. However, funding constraints and heavy model shop commitments have forced this effort to be abandoned, and a simple mechanical device capable of only visual readout will be added to the system in lieu of the more sophisticated subsystem originally envisaged.

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

1. Dunne, J. A., "Ross Filters as Dispersive Elements in X-Ray Spectroscopy," Fifth National Meeting of the Society for Applied Spectroscopy, Chicago, Illinois, June 13-17, 1966.

Publications in the Open Literature

1. Dunne, J. A., "The Application of Ross Filters to the Non-Dispersive Analysis of Aluminum and Silicon," Norelco Reporter, Vol. XIII, No. 1, January - March 1966 (reprinted as JPL TR 32-917).

'L SPS Contributions

Dunne, J. A., "Scanning Mode Options for a Lunar Diffraction Experiment," SPS 37-35, Vol. IV, October 31, 1965, pp. 199-202.

ꟷBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

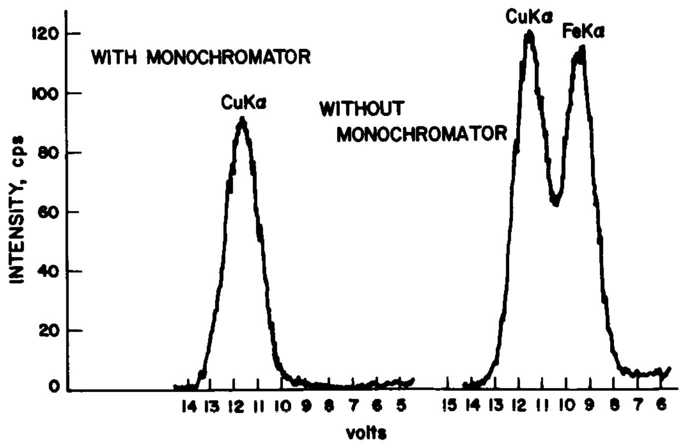


Fig. 1. Pulse amplitude distribution curves for alpha - Fe(110) with copper K - alpha radiation

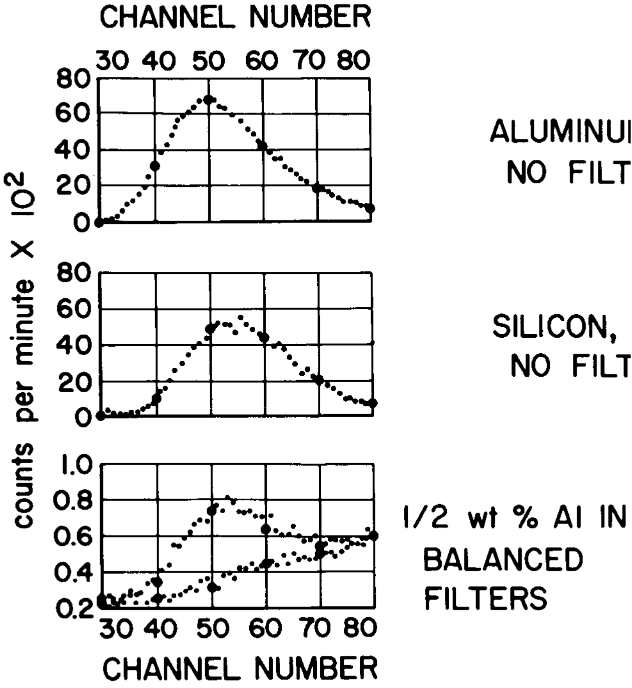


Fig. 3. Analysis of aluminum in silic using balanced filters

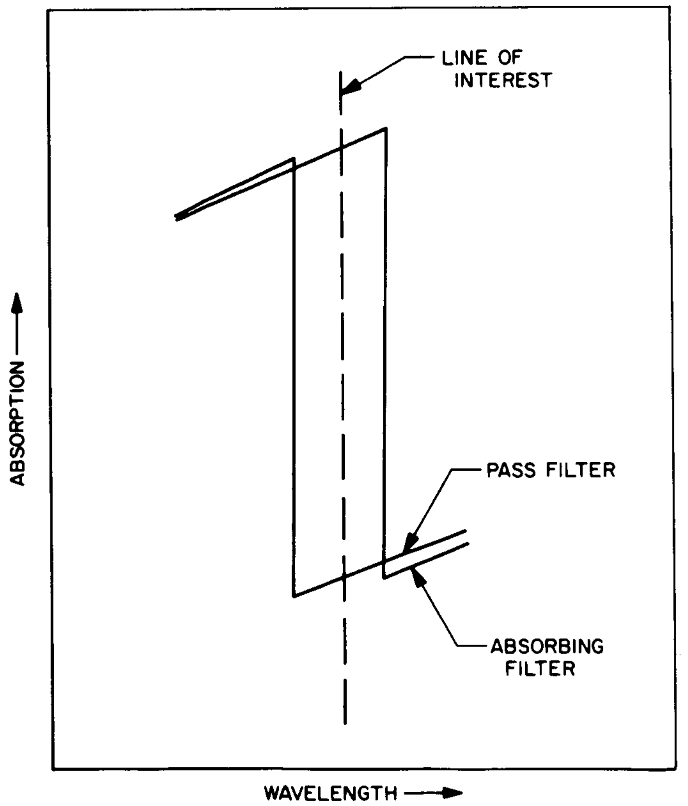


Fig. 2. The balanced filter principle

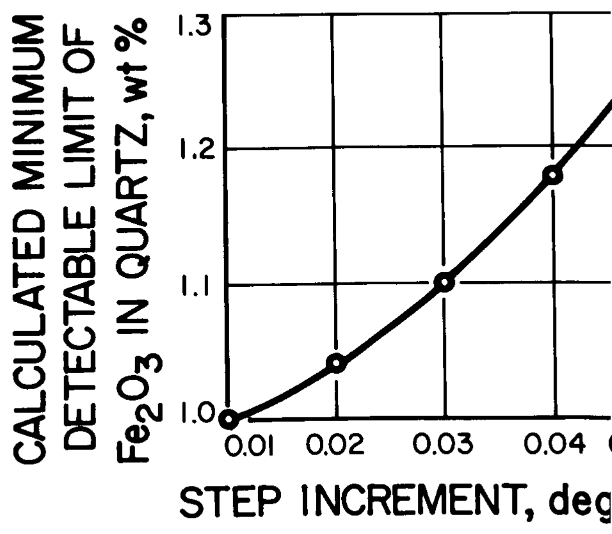


Fig. 4. Effect of step scan incremen minimum detectable limit

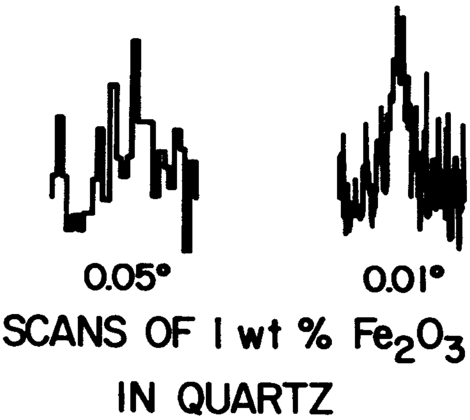


Fig. 5. Scans of curve of Fig. 4

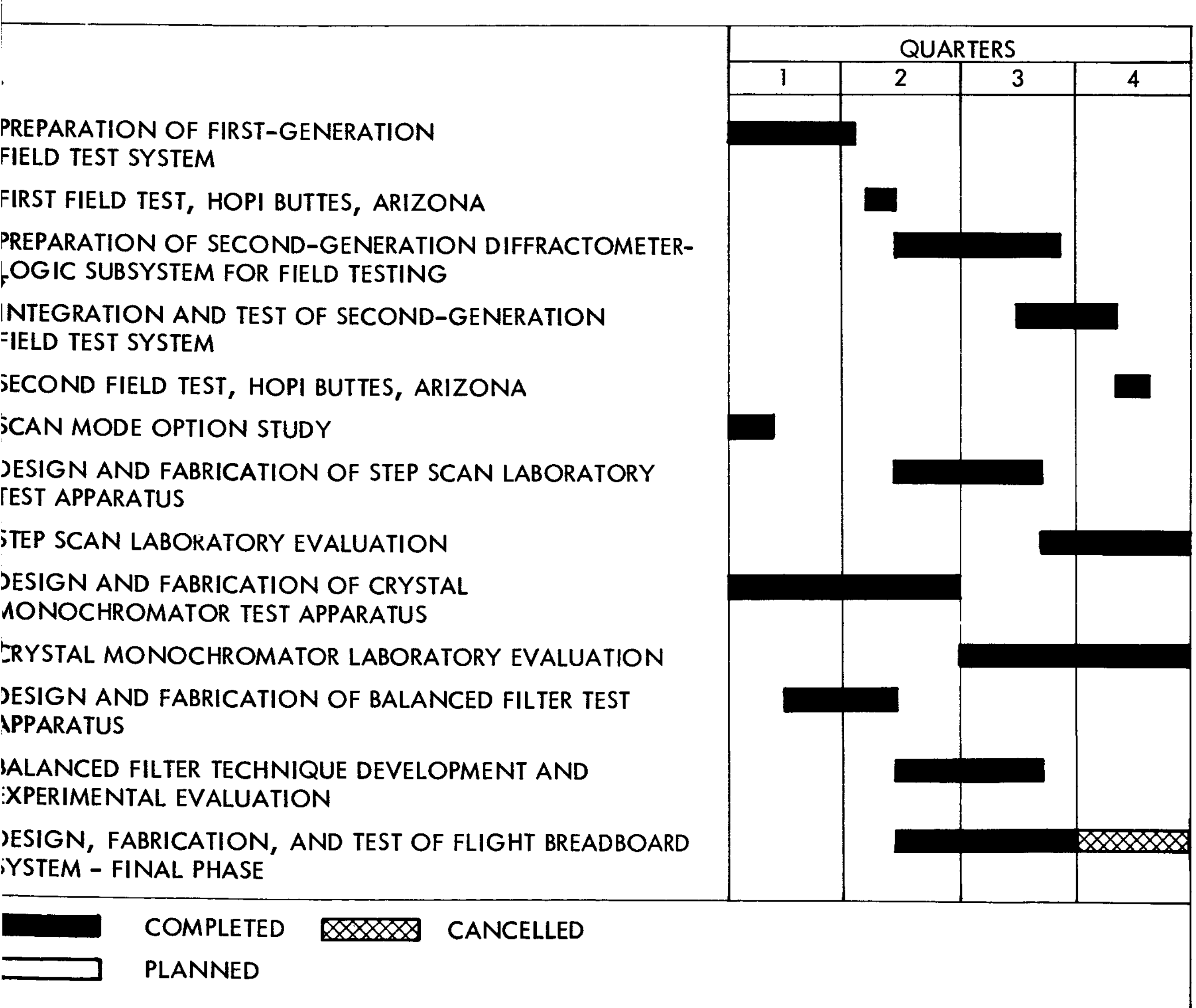


Fig. 6. Program milestones for FY 1966

FLIGHT MODEL INTERFEROMETER
NASA Work Unit 185-37-20-10-55 (818-01-06-70*)
JPL 544-67090-1-3250
Reinhard Beer

OBJECTIVE

The objective of this task is to develop a flightworthy, high-resolution infrared interference spectrometer for atmospheric analysis on advanced planetary missions.

INTERFEROMETER

The present optical breadboard has been found to have excessive inertia (in the moving element) to be overcome by any useful drive system. Furthermore, the cat's-eye reflectors procured from Perkin-Elmer have been found to be rather difficult to focus to interferometric standards. Based on calculations performed by R. Beer and D. Marjamiemi (to be published in Applied Optics, July or August 1966), new cat's-eyes have been designed which are 1/3 the size and much more conveniently mounted and focused.

A statement of work has been written which specifies the required performance of the servo-controlled drive system for the interferometer. A bidder's conference was held on June 2, 1966 in preparation for a possible proposal request. It is hoped that if a contract results, it can be let by August 1966 with completion by December 1966.

Preliminary studies have been made for the infrared portion of the system. These will be completed and procurement commenced during the next half year.

PUBLICATIONS DURING FY 1966

1. Beer, R., "Unique Construction Makes Interferometer Insensitive to Mechanical Stresses," NASA Technical Brief 65-10295.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

1. Beer, R., "Fourier Spectrometry from Balloons," Applied Optics, to appear in February 1967. (The article is currently in preparation.)

*Transferred to Voyager Project in FY 1966.

LUNAR AND PLANETARY GEOPHYSICAL MODELS

NASA Work Unit 185-37-20-12-55
JPL 383-32901-2-3250

Ray L. Newburn, Jr.

OBJECTIVE

Environmental models will be furnished for the bodies of the solar system as follows: the Moon (to support Surveyor), Mars (to support Mariner and Voyager), and ultimately Venus, Jupiter, Mercury, comets, and other objects which may be the goals of advanced planetary missions.

LUNAR MODEL

A first version of a Lunar Scientific Model has been completed by J. de Wys, R. Choate, E. Miner, et al., and is being revised for publication as a Surveyor project document. The document will be updated as new data become available from Surveyor, Lunar Orbiter, and Earth-based work. The scientific work behind the project handbook is being written as several technical memoranda, and these will be available within six months. Choate has taken part in most of the meetings of the SLUMP committee on lunar surface properties, giving papers on soil mechanics at two of them.

MARS MODEL

Many of the results of the ground-based program of observation during the 1965 apparition of Mars and of the Mariner IV probe flight are only now becoming available. The study of Martian atmospheric motion mentioned in the last semi-annual report is now well underway and giving interesting results. It will continue during the coming fiscal year, largely under the cognizance of R. McClatchey (under Atmospheric Physics). A new density profile has been produced by J. Gunn. Surface pressure information has become available from the optical astronomy program, the work of H. Spinrad, R. Schorn, L. Gray, et al. New data on atmospheric composition are coming from the Fourier spectroscopy of P. Connes, J. Connes, and L. Kaplan. The major effort of this work unit during FY 1967 will be the synthesis of a new Mars model from these and other data. Meanwhile interim data are being fed to Mariner and Voyager projects in memos and meetings.

ADVANCED MISSIONS

R. Newburn was a member of the Mariner 1967 Venus Experiment Evaluation Committee. He also gave a paper "Current Knowledge Regarding Venus" at the Mariner 1967 Project Organization and Orientation Meeting at JPL on February 24-25, 1966. Newburn worked with R. G. Brereton of the Advanced Technical Studies Office on three different advanced mission planning documents: "Sample Jupiter Science Objectives and Typical Experiments For Use in Advanced Planetary Probe Mission Studies," "Venus: Preliminary Science Objectives and Experiments For Use in Advanced Mission Studies," and "Venus/Mercury Swing-By: Preliminary Science Objectives and Experiments For Use in Advanced Mission Studies." Work of this type is continuing, the work underway at the present time being on a Comet Mission.

PUBLICATION DURING FY 1966

Papers presented at Meetings and Symposia

1. Choate, R., "Lunar Slope Angles and Surface Roughness from Ranger Photographs," University of Michigan Symposium on "Remote Sensing of Environment," April 1966.

2. Newburn, R., "Scientific Interests for Advanced Missions," AIAA Symposium o Advanced Unmanned Deep Space Missions, March 23, 1966.

JPL Project Document

1. de Wys, J., Choate, R., Miner, E., et al., Surveyor Lunar Scientific Model, Project Document No. 54, issued in sections during the past year.

JPL Technical Memorandum

1. Brereton, R. G., Newburn, R. L., et al., Venus: Preliminary Science Objectives and Experiments for Use in Advanced Mission Studies, JPL TM 33-282, May 1, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

Publications in the Open Literature

1. Choate, R., "Lunar Slope Angles and Surface Roughness from Ranger Photographs," Proceedings of the University of Michigan Symposium on "Remote Sensing of Environment," in press.

JPL Technical Reports

1. Choate, R., "Evaluation of Surveyor Exhaust Effects on the Moon" (a preliminary version dated March 1 has been circulated locally, the revised version for open release will follow in a few weeks).

JPL Technical Memorandum

1. Brereton, R. G., Newburn, R. L., et al., Venus/Mercury Swing-By with Venu Capsule, in press, release date July 11.

GAMMA RAY SPECTROSCOPY
NASA Work Unit 185-37-20-13-55
JPL 383-31301-2-3250
A. E. Metzger

BJECTIVE

A gamma ray spectrometer will furnish data on the chemical composition of ınar and planetary surfaces by measuring the intensity and characteristic energy of mitted radiation. On an orbiting or roving vehicle it should detect gross differences ı the composition of different portions of the lunar or Martian surface. The same ıstrument can be used to measure energy spectra of galactic or extragalactic ources. The objective of this program is to show the capability of gamma ray/ -ray spectroscopy for the above applications, to optimize instrument design, and to evelop techniques of data analysis and interpretation.

ROGRESS

A gamma ray detector configuration has been sought which possesses good fficiency and which can also offer a substantial improvement in spatial resolution ver a simple single crystal. During the previous reporting period a two-crystal ompton telescopic system was assembled. In this configuration, the signals from ıe two detectors are summed when they occur in coincidence, and the combined output is transmitted to a pulse height analyzer for energy discrimination and spectral isplay. A substantial number of tests have been run with the Compton telescope as function of crystal thickness and diameter, crystal separation, incident energy, ıcident angle, and signal enhancement over background. When the leading crystal constrained to respond to a limited range of deposited energy, the angular resoluon becomes very good and can be improved further with the addition of shielding Fig. 1); however, the good spatial resolution and background reduction of the telecope is offset by a large loss in counting efficiency (Table 1). An alternative design ased on single crystal detection with surrounding anticoincident shielding appears ıore suitable for an orbiter mission where the field of view is changing rapidly.

Design of a large area thin window proportional counter for the detection of rays in the 1- to 10-kev range is proceeding. A photograph of the breadboard unit shown (Fig. 2). This unit has functioned successfully for several weeks, and esign modifications are planned to extend this to a minimum of six months. An ccessory gas-reservoir system has been tested which minimized pressure changes ue to leakage.

A set of laboratory experiments is planned to test the fluorescent response of imulated lunar materials (granites, basalts, chrondites) to solar X-rays and harged particles. The first step in this program has been to simulate the expected olar X-ray spectrum. This has been carried out by measuring the response of varıus X-ray targets under suitable operating conditions. Figure 3 shows the match to ata obtained by Culhane from the quiet Sun at the solar maximum. Selected mateials will be exposed to these composite spectra in the next stage of work.

Tests with a ceramic and glass photomultiplier tube have been successful. he resolution of the tube was good, and its inherent K^{40} content measured 20% to

30% less than that of a typical all-glass photomultiplier tube. A more rugged cerar and metal tube of similar internal design is being ordered.

The University of California at Berkeley has been kind enough to make thei Bevatron accelerator available for simulation studies of induced gamma ray activi ties. Compliance with the prior administrative formalities on the part of UCRL, JPL, AEC, and NASA is proceeding at a measured pace.

During this reporting period proposals were submitted for two forthcoming NASA flight programs, Apollo AAP Earth Orbital and Mariner 1969. The former favorably reviewed and awaits mission definition; the latter was placed in Category During the next six months detector development will continue, the accelerator an other simulation studies will be initiated, and work on gain stabilization for both gamma ray and X-ray detector systems will be resumed.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

Table 1. Comparative responses of several gamma ray detector configurations

Source angle, deg	Counting rates at 0.66 MeV-Cs^{137}, counts/min					
	A	B	C	D	E	F
0	14,791	14,831	314	499	328	439
7.5	14,536	2,502	324	505	93	119
45	14,153	2,010	11	422	6	103
180	14,800	3,230	3	300	2	237

Counting rate	Configuration	Discrimination	Shielding[a]
A	Single crystal[b]	--	no
B	Single crystal	--	yes
C	Telescope[c]	250 KeV	no
D	Telescope	none	no
E	Telescope	250 KeV	yes
F	Telescope	none	yes

6- x 18- x 1/2-in. lead.

3- x 3-in. crystal.

3- x 3-in. and 4- x 8-in. crystals; 10-in. separation.

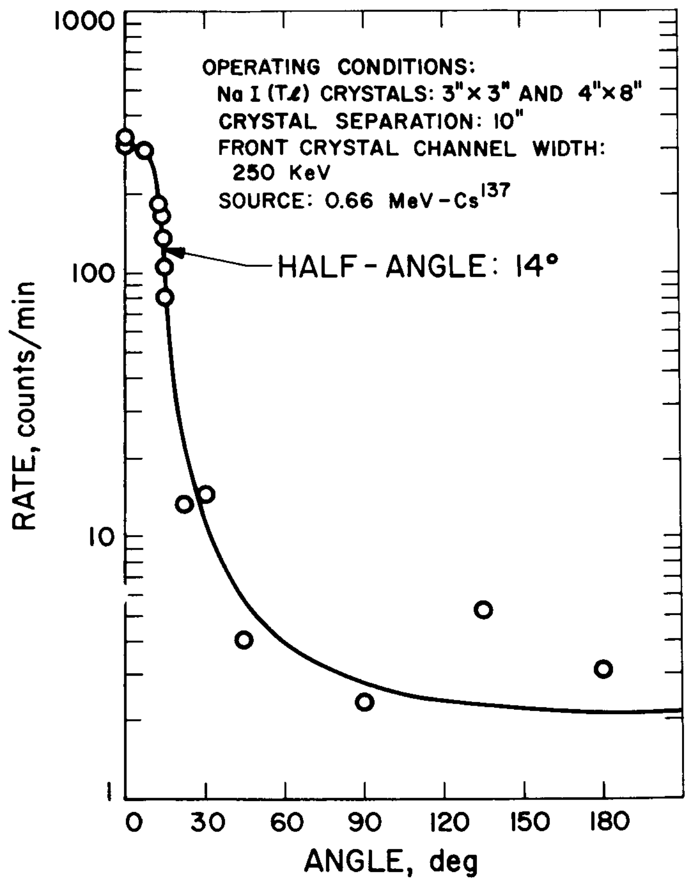


Fig. 1. Spatial resolutions with Compton telescope

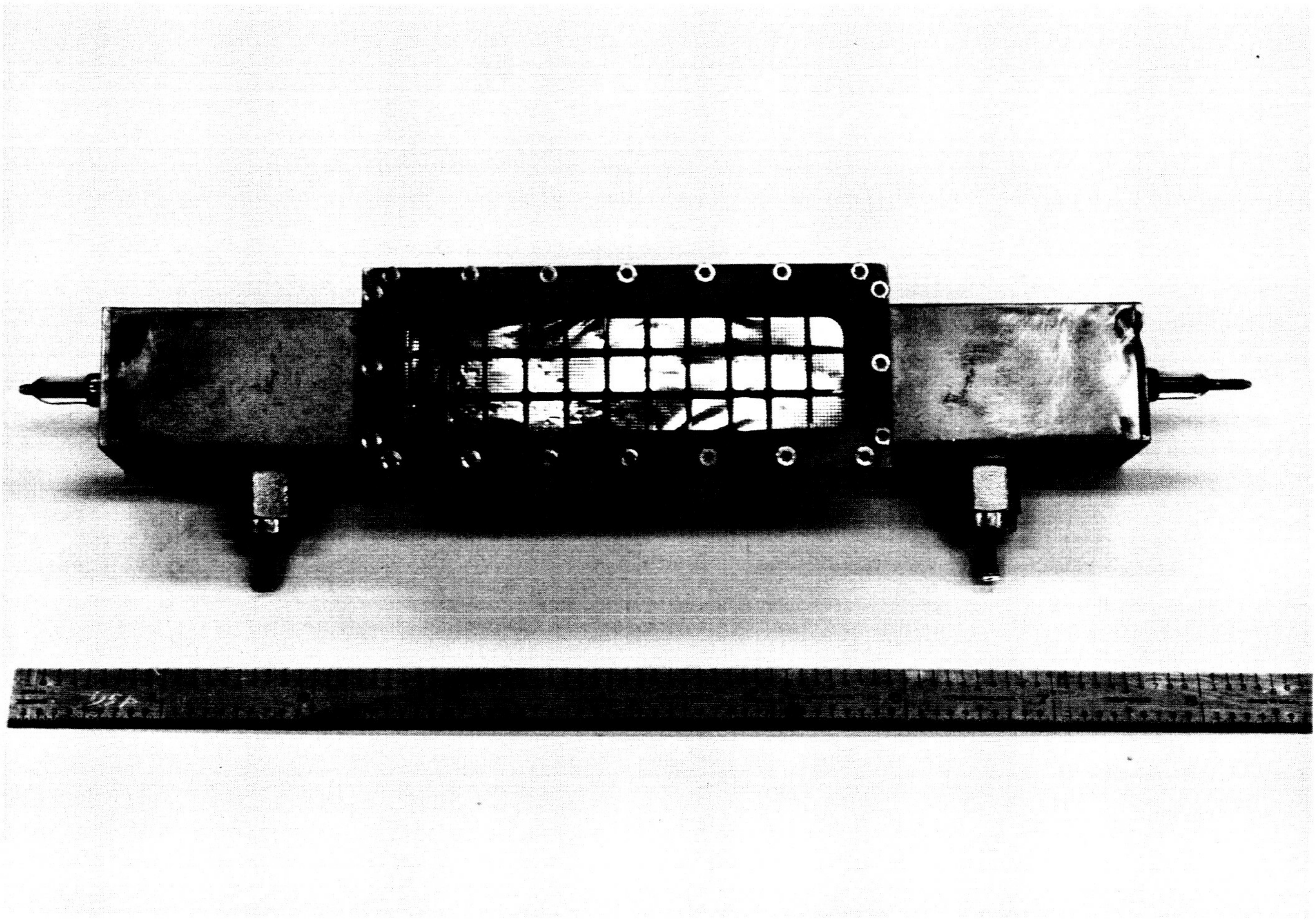


Fig. 2. Large window area proportional counter

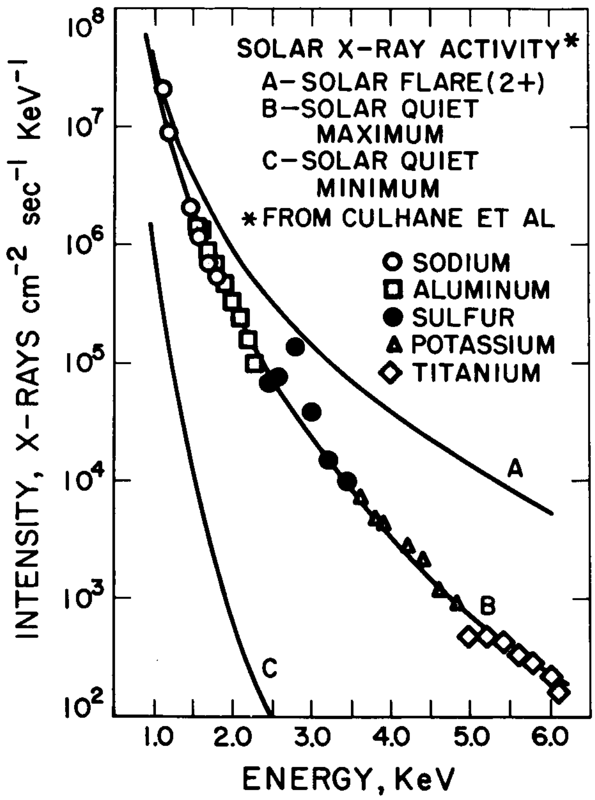


Fig. 3. Laboratory simulation of solar X-ray flux

GEOSAMPLING (GEOLOGICAL SAMPLING)

NASA Work Unit 185-37-20-14-55-08 (818-01-06-70*)
JPL 544-67070-1-3220
G. M. Hotz

OBJECTIVE

The objective of the geosampling effort is to develop devices which will deliver to analytical instruments suitable samples of geological material representative of the location from which the sample was obtained.

SUMMARY

Contractual efforts have continued on methods of obtaining particle-size control in fragmenting rock, and a new contract has been let to develop and test two JPL drill-sampler concepts. In-house efforts have concentrated on further testing of transport devices and on design and construction of complete breadboards of sampling systems.

CONTRACTUAL ACTIVITIES

1. Contract 951480 (previously referred to as 951178, Phase II: $24,500, about June 1, 1966 to January 1, 1967, Contractor: Hughes Tool Company, Oil Tool Division, Houston, Texas).

   Purpose:

   (a) Test, evaluate, and develop Government-furnished JPL Geological Sampler Concept A-1 breadboard. (This is a rotary percussive drill sampler embodying drilling parameters developed under Surveyor II X-ray diffractometer program and incorporating axial vibratory sample transport; it is largely untested except in drilling rock.)

   (b) Modify breadboard, if indicated, through addition of an abrading cone sieve to improve performance in particulate material.

   (c) Design and construct breadboard of JPL drill sampler concept (B). (This is a drill sampler essentially the same as A-1 except that it employs helical sample conveying.)

2. Contract No. 951398: $24,900, Hughes Tool Company, Oil Tool Division, Houston, Texas, about December 3, 1965 to (330 days). Progress on this contract has been in familiarization with the JPL breadboard drill and operating it over a large matrix of operating parameters and determining drill rates and particle-size analyses to attempt to determine how to achieve desired particle-size control. Results to date appear to indicate that desired results cannot

*Transferred to Voyager project in FY 1966.

be achieved through varying operating parameters alone, but that a change in bit design will be required as well.

3. Contract No. 951422: $24,800, National Research Corporation, Cambridge, Massachusetts, about January 1, 1966 to September 1966. Objective of this contract is to investigate feasibility of abrasive techniques for geosampling with emphasis on particle-size control, transport of material, and overburden removal. Progress to date has consisted of familiarization with surface grinder operation, problems connected with gathering and sizing powders, and contamination of sample with diamond matrix material. To date, National Research Corporation has been having difficulty in producing large particle sizes but has found that coarser grits help. We have redirected this contract from development of a point contact grinding wheel to a continuous wheel.

IN-HOUSE ACTIVITIES

In-house efforts have been directed toward continued development and testing of helical conveyors and abrading devices and the development of breadboard samplers incorporating these elements.

Abrading Drum Bulk Sampler

This sampler, shown in Fig. 1, is a variation of the abrading drum sieve sampler shown in Fig. 2 of the previous semiannual report with two basic difference First, it has large opening scoops for sample entry to permit internal tumbling and abrading action of large-sized particulate before size sorting at entry to the collecting chamber; after screening, large rocks are ejected. Second, it employs batch aerosol transport and hence should be insensitive to lunar or planetary atmosphere lack of it. This unit is presently being fabricated.

Flexible Helical Screw Conveyor Rotary Drill Sampler

This sampler, which employs a single motor, is shown in Fig. 2; it has approximately 18 in. of deployment and is mechanized to deploy rapidly until it reaches particulate or rock, then slows down in particulate, and against rock it exerts a preset thrust. It should be capable of drilling into anything up to rock of medium hardness (say serpentine) and should be a good particulate sampler. This sampler, also presently being fabricated, was designed to fit within a 30-in. ID spherical capsule.

Rigid Helical Screw Conveyors

A considerable amount of testing has been done on this conveying device to determine its transport rates, power requirements, durability, its comminution of sample, and screw and casing wear and resultant effect upon conveyor performance A test rig was built on which such devices are tested,and Fig. 3 and 4 show some of the results obtained. Results to date indicate that the helical conveyor has a high transport rate (higher than generally needed) and requires relatively low power. It appears that the silicone rubber sleeve has many advantages over metal sleeves and appears suitable for geosampling, although suspect for biosampling.

ʼechnical Direction of Biosampler Contract

Personnel engaged in the helical screw conveyor task have also been acting as echnical directors of a NASA-Headquarters-funded biosampling contract with the eronutronic Division of the Philco Corporation, Newport Beach, California, JASw-1065, Modification No. 2. This work is aimed at the development of two types f mechanical samplers for basis of comparison with the pneumatic biosampler eveloped by Litton Systems, Minneapolis, which comprises the bulk of JPL bioampler development to date. Various acquisition, abrading, and transport devices nder development on geosampling were considered and evaluated during the coneptual design study by Aeronutronic.

CTIVITIES DURING NEXT PERIOD

1. Monitor the outside contract noted above.

2. Continue in-house development and testing of small, simple, lightweight sampling elements and incorporate these into breadboard samplers.

UBLICATIONS DURING FY 1966

ontractor Report

. "Final Report of Preliminary Design of a Geologic Sample Acquisition and Transport Device," October 1965. JPL Re-order 65-757. JPL Subcontract 951178 with Hughes Tool Company, Houston, Texas.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

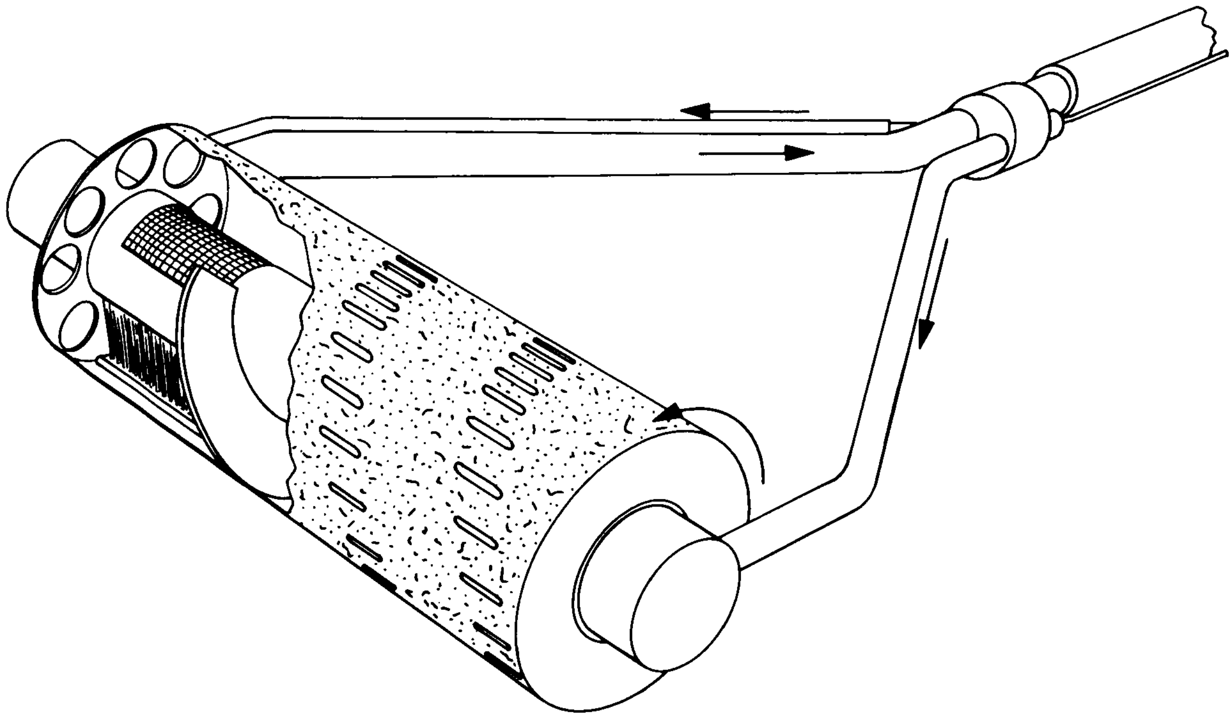
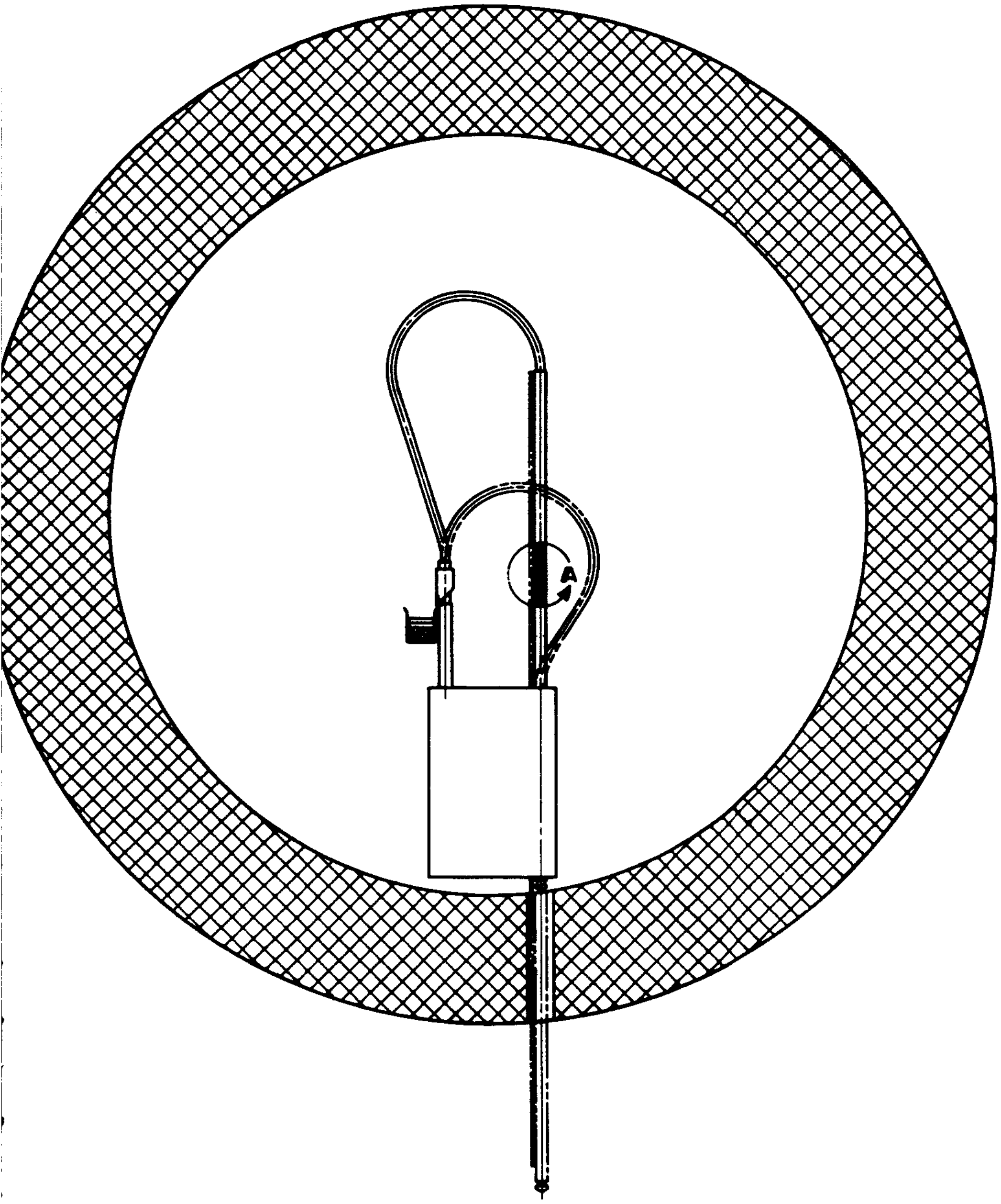


Fig. 1. A brading drum bulk sampler



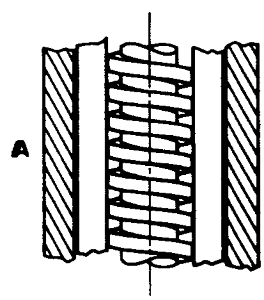


Fig. 2. Flexible helical screw conveyor rotary drill sampler

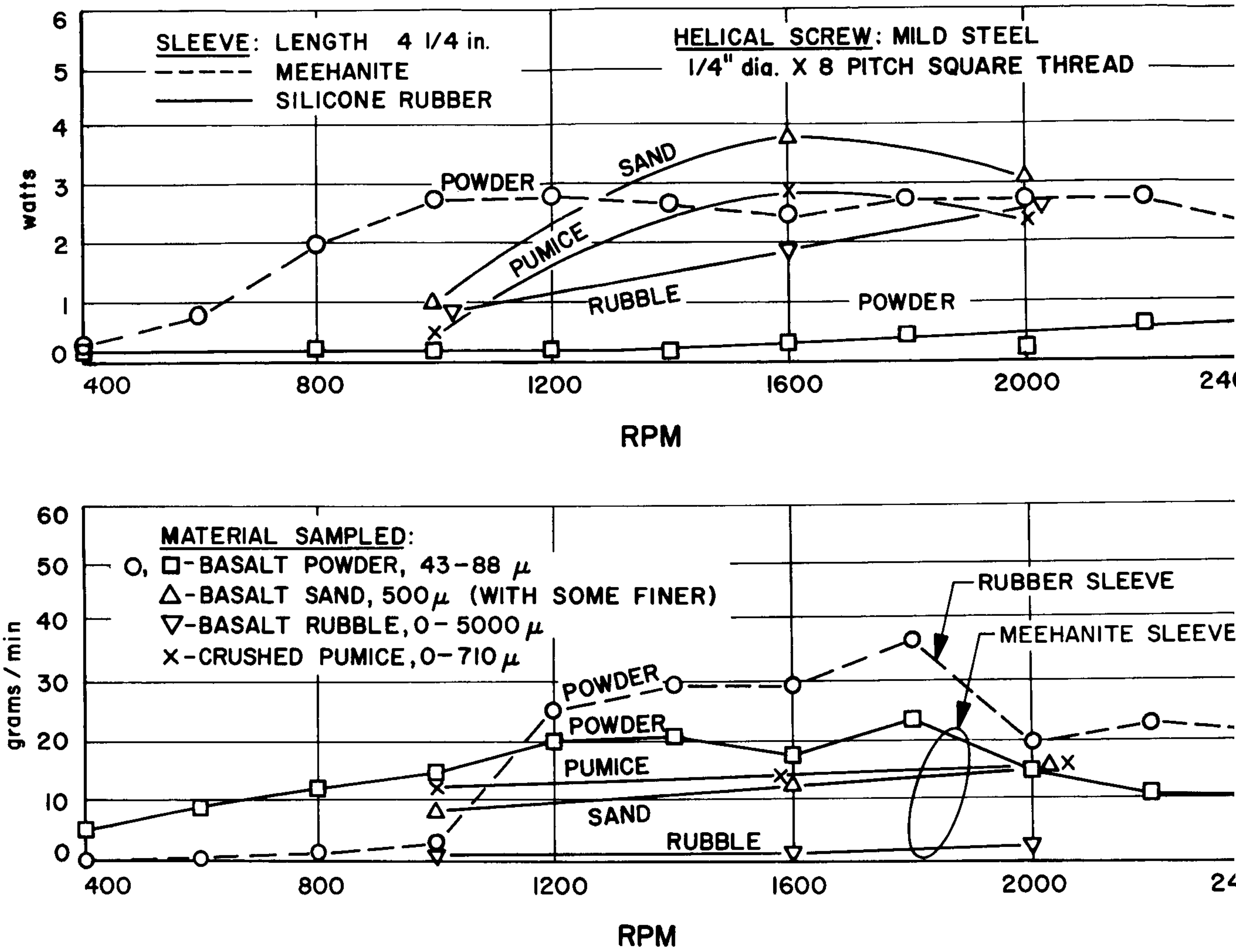


Fig. 3. Rigid helical screw conveyor power and transport rate vs rotational speed

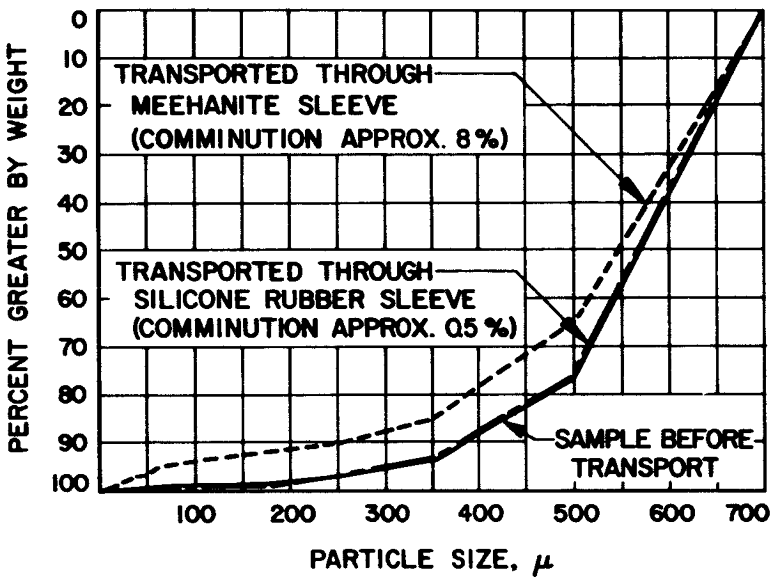


Fig. 4. Particle-size distributions of quartz sand before and after transport by rigid helical screw conveyor

MICROWAVE RADIOMETER DEVELOPMENT
NASA Work Unit 185-37-25-01-55
JPL 383-30901-1-3250
F. T. Barath

OBJECTIVE

The objective of this task is (1) to design, develop, fabricate, and test high-performance microwave radiometers in the 3 cm to 1 mm region, (2) to utilize and evaluate these radiometers in the framework of a ground-based radio astronomy observation program specifically directed at studying the Moon and the planets, and (3) to develop techniques and instrumentation for future spacecraft of the Voyager class.

PROGRESS

During this reporting period, the work was in the following areas: (1) Venus was observed with the variable-frequency radiometer in the 13-mm wavelength region. The observations were done both at Table Mountain (10-ft antenna) and Goldstone (30-ft antenna). The data are being reduced by the Radio Astronomy Group. (2) A precision 18-ft antenna for the Table Mountain facility was ordered in February and is due for delivery in August. The antenna will be installed and thoroughly checked out before being put into practically continuous operation. (3) The contract for a low-noise 8-mm front-end was placed in February, with delivery in December. Good progress is reported; the prototype is to be operational in August. The system will be tested in the laboratory and then installed on the new 18-ft antenna. (4) The in-house construction of an 8-mm radiometer system compatible with the low-noise front-end is almost complete. It will be used for the checkout of the 18-ft antenna and for scientific observations. The low-noise front-end will be installed in this system upon receipt. (5) All essential parts for an 8-mm interferometer remotely synchronized local oscillator system have been ordered. Delivery will take a long time, but a breadboard system is expected to be operational by the fall. A simplified field trial will be scheduled if the breadboard tests are satisfactory.

PUBLICATIONS DURING FY1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

MASS SPECTROMETERY
NASA Work Unit 185-37-26-01-55
JPL 383-31001-2-3250
C. E. Giffin

OBJECTIVE

The long-range objectives of this unit are twofold. The first is the measurement of the ionic and neutral composition of the lunar atmosphere and the second is the compositional analysis of the Martian atmosphere. The current fiscal year objectives will be finalization of the design and testing phase of a random noise quadrupole mass spectrometer (Q-pole MS) prior to breadboard development. In addition, the final testing of the Martian atmosphere mass spectrometer breadboard will be completed, emphasizing the aspects of data retrieval, ion pumping, and molecular leak inlet system.

LUNAR ATMOSPHERE MASS SPECTROMETER

Research for a nonthermal ("cold") electron source was continued. Figure 1 is a schematic drawing of the electron source under test. When a voltage is placed across the resistive coated annular rings, secondary electron emission occurs. This current is initiated by the beta particles from the tritiated titanium foil placed between the rings. Attempts are being made to generate secondary electron currents perpendicular to the vertical axis of the device of sufficient intensity and of the proper energy so that ions created in the region of the axis can be extracted for mass analysis by a quadrupole mass spectrometer. Figures 2 and 3 show data obtained from the annular ring electron source. It can be seen from Fig. 2 that the secondary electron yields become an exponential function of the voltage applied to the rings at the high voltage levels. When Faraday cage collection techniques are used instead of the thin-wire collector shown in Fig. 1, electron currents comparable to those collected by the repeller grid are obtained. By varying the diameter of the Faraday collector one obtains a measure of the geometric spreading of the secondary electron beam. Data taken from various collector diameters have shown that the electron beam is quite highly collimated--a condition which is desirable for use in generating ions for a mass spectrometer. The data in Fig. 3 demonstrate the narrow energy distribution obtained from this nonthermal source.

At present the electron currents being obtained are not high enough for efficient ionization of a low density atmosphere. The limitation on the present source is the voltage level that can be applied to the resistive coated rings. Higher resistance rings are being obtained so that currents in the tens of microamperes will be available for ionization. In addition promethium-147 and other radioactive materials will be investigated as temperature-stable sources of primary beta particles. Different geometries of resistive electron multipliers will also be studied which may offer electron currents in the hundreds of microamperes.

The results of our work with the supplementary field quadrupole mass spectrometer show that we can indeed get higher resolution than through normal quadrupole operation. However we have been hampered by the lack of sufficiently controllable supplementary oscillators for determining the optimum operating parameters of the instrument. The Tulsa Division of AVCO has been contracted to design and construct special electronics to be used with the JPL quadrupole. In the interim the JPL

electronics are being modified to obtain the optimum values of the supplementary voltages and frequencies. It has been found that the quadrupole rods of the present JPL spectrometer must be lengthened to obtain the full benefit of supplementary field operation. This will be done in the next six months.

Figure 4 is a block diagram of the high-sensitivity quadrupole mass spectrom eter. As can be seen in this figure the mass spectrometer scanning circuit is "slaved" to the address registers of a 1024 multichannel analyzer (MCA). At the initiation of a data sampling sequence the integrating time base (ITB) unit starts advancing the address of the MCA and effecting pre-set dwell times on each of its 1024 channels. In addition the quadrupole field voltages are stepped in coincidence with the MCA address. Hence each channel represents a different portion of the mas scale. Individual ions are counted at the output of the mass spectrometer and a 10^6: dynamic range is obtained in partial pressure analysis. A single mass scan can be accomplished in a minimum time of 50 millisec and a maximum time of 36 min. Dat from the entire 1024 channels can be read out in less than 2 sec.

PLANETARY ATMOSPHERE MASS SPECTROMETER

The data handling problems peculiar to a mass spectrometer are continuing t be studied. Peak detection circuits are being designed, constructed, and tested. Use is being made of an analog-to-digital conversion system that simultaneously samples both the acceleration voltage (for mass identification) and ion current. The system has a 40 line/sec readout capability limited only by the mechanical printer. With the help of the Space Instruments Systems Section a digital mass scanning system is also being studied under the data handling subtask. Computer calculations ar being carried out to obtain the design parameters for fabrication of a silicon on sapphire diode matrix microcircuit. This circuit will produce a precisely linear mass scale which will allow a wide variety of data sampling modes completely controlled b (or servoed to) the mass spectrometer. It is felt that this approach will ensure com patibility over a wide range of telemetry constraints. This work is discussed more fully under the NASA 186 Task entitled Science Data Automation Systems (186-68-03-04-55).

Two high-altitude flights were completed with the breadboard mass spectrom eter on an Air Force high-altitude research aircraft. The instrument functioned per fectly in the first flight, but the ion currents in the mass spectrometer were of very low intensity due to a last minute change in flight plan. The second flight was a failure because of an unexplained high voltage arc-over.

High-impact tests with various permanent magnet materials were performed and the preliminary results are very encouraging. Tests at up to 2000 g were made and no fracturing or loss of magnetic field were observed. These same magnet materials will be tested again in the actual magnetic geometry required by a magnet sector mass spectrometer.

It is proposed for FY 1967 that a double-focusing mass spectrometer be constructed so that parts per million and isotopic analyses can be made on the earliest Voyager mission. Little increase in weight and power will result from the tremendous increase in scientific capability gained over the present single-focusing instrument.

A digital scanning circuit will be constructed and tested with the present breadboard mass spectrometer.

Because of the possibility of an entry capsule prior to Voyager, a complete evaluation of the present breadboard electronics will be made. Redesign will be done where improvements can be made in weight and power as well as where incompatibilities exist with present-day flight standards.

The data retrieval studies will continue with emphasis on peak detection and sampling controlled by the digital scanning circuit.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

Papers to be Presented at Symposia

1. Giffin, C. E., and Sieradski, L. M., "A Supplementary Field Quadrupole Mass Filter for Low Pressure Analysis," ASTM Committee E-14 on Mass Spectrometry and Allied Topics, May 1967.

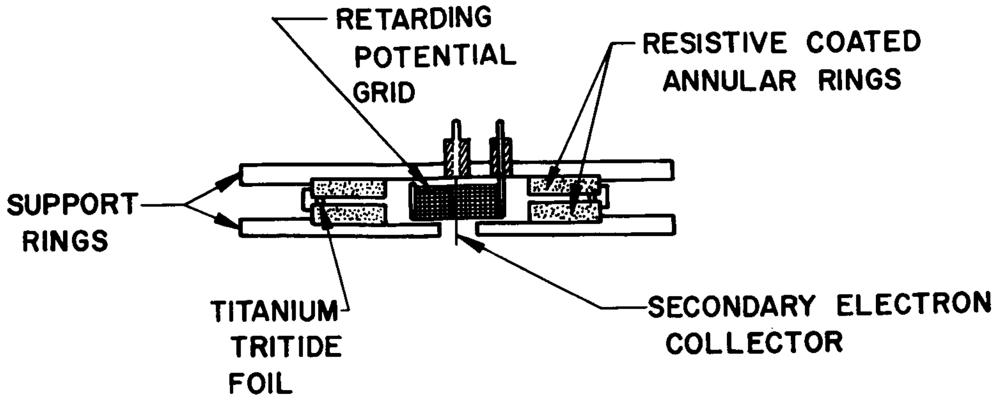


Fig. 1. Schematic of annular electron source

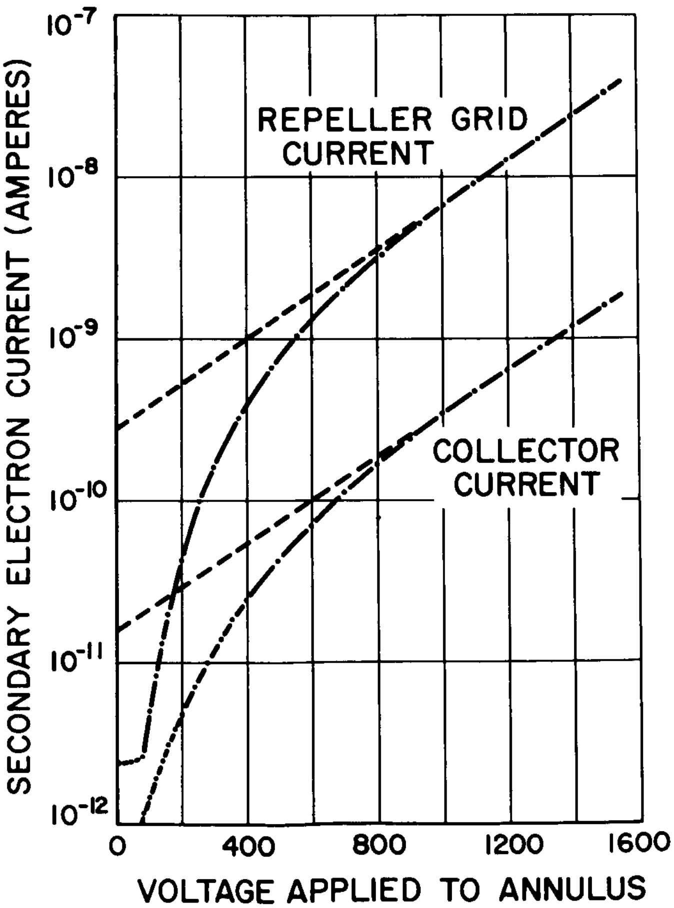


Fig. 2. Annular electron source secondary electron yield

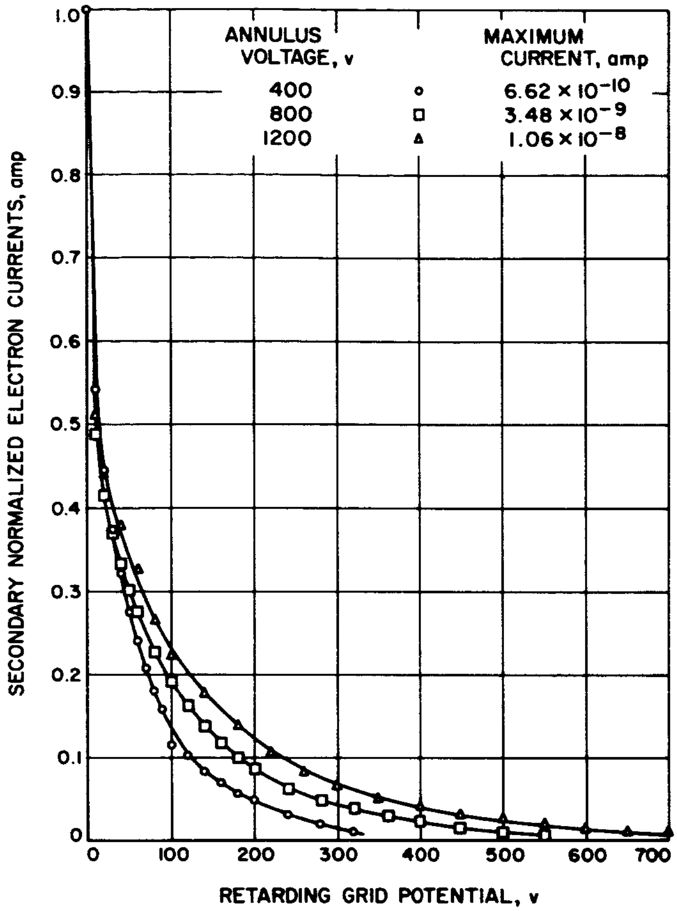


Fig. 3. Secondary electron energy spectrum of annular ring electron source

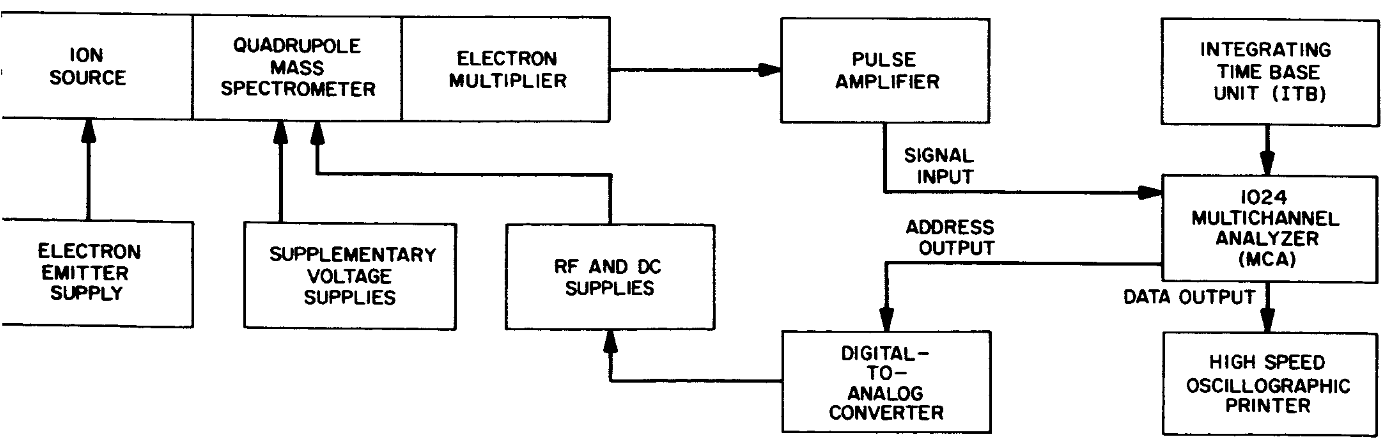


Fig. 4. Schematic diagram of JPL high-sensitivity mass spectrometer

INTERFEROMETRIC INVESTIGATIONS
NASA Work Unit 185-37-26-06-55
JPL 383-30601-2-3250
Reinhard Beer

OBJECTIVE

The objective of this task is the continued investigation, development, and use of infrared interference spectrometers as high-resolution, high-luminosity devices in the laboratory and field.

PLANETARY INTERFEROMETER

The MK II 8000-4000 cm^{-1} planetary interferometer employed by P. & J. Connes at the Coudé focus of the 78-in. telescope at Haute Provence, France, is now operating at its design limits in a routine fashion. JPL is receiving spectra of Venus at 0.1 cm^{-1} resolution, which are now essentially detector noise-limited. The measured gain in (signal/noise x resolving power) is about 10^{10} over the best grating spectrograms produced to date. The instrument is destined to become part of the permanent installation at Haute Provence.

The spectral reductions are being carried out at JPL under the cognizance of Dr. L. D. Kaplan in conjunction with the Infrared Spectroscopy of Synthetic Atmospheres Project. The spectra are being published. A description of the MK II instrument and its performance will appear, by P. and J. Connes, in the July issue of the Journal of the Optical Society of America.

The MK III instrument is under construction at JPL. It is very similar, in concept, to the MK II but will operate, principally, in the 3300 to 2500 cm^{-1} region. The construction and testing program proceeds on schedule. Its first use will be at the coudé focus of the 24-in. telescope at Table Mountain during the fall of 1966.

FAR INFRARED INTERFEROMETER

The far infrared (1000 to 100 cm^{-1}) interferometer, which was first flown on a balloon during August 1965, is currently being modified and prepared for its second flight. This event is scheduled for October 1966. Our collaborator on this project is Dr. D. G. Murcray and his associates, of the University of Denver.

MEETINGS

One of the major events of the past half year was a trip to Paris, France, made by R. Beer for the purpose of attending the 2nd Conference on New Methods of Instrumental Spectroscopy (25-30 April) and the 7th Meeting of the International Commission for Optics (2-7 May). The earlier meeting was almost entirely concerned with interference spectroscopy and as such was an extremely valuable occasion for meeting the participants, since it is 9 yrs since the first conference took place.

The second conference (IC07) was concerned with more fundamental aspects of physical optics but provided us with an excellent opportunity for keeping abreast of these most important topics.

Particularly valuable during this period were discussions held with P. Connes (CNRS Bellevue) and J. Connes (Paris Observatory) on Fourier spectroscopy of planets, J. Lequeux (Paris Observatory) on Fourier spectroscopy from balloons, J. Ring (University of Hull) on novel methods of Fourier spectroscopy, and P. Bouchareine (CNRS Bellevue) on his autocorrelation spectrograph employing the Girard grille.

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

1. Beer, Reinhard, and Cayford, A. H., " An investigation of a fundamental intensity error in Fourier spectroscopy," 2nd Conference On New Methods of Instrumental Spectroscopy, Paris, France (April 25-30, 1966).

2. Beer, R., "A balloon-borne Michelson interferometer for solar spectroscopy in the 10-100 micron region," 2nd Conference On New Methods of Instrumental Spectroscopy, Paris, France (April 25-30, 1966).

Publications in the Open Literature

1. Beer, R., "Decrement of the Solar continuum in the far infrared," Nature, 209, 1226, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

Open Literature

1. Connes, P., Connes, J., and Kaplan, L. D., "High Resolution Planetary spectra obtained by Fourier spectroscopy," Science (in press).

2. Beer, R., and Marjaniemi, D., "Wavefronts and construction tolerances for a cat's-eye retroreflector," Applied Optics (in press).

3. Beer, R., "Fourier spectroscopy from balloons," invited paper by Applied Optics, to appear in February 1967.

JPL Technical Memorandum

1. Connes, P., Connes, J., and Kaplan, L. D., Planetary Spectra obtained by Fourier Spectroscopy I: Mars 1.2-2.5 microns (in preparation).

DETECTION OF LIFE-RELATED COMPOUNDS
NASA Work Unit 185-37-26-09-55
(818-01-06-70*)
JPL 544-67040-1-3260
W. F. Wilhite
C. E. Giffin

; CHROMATOGRAPH COLUMN and DETECTOR DEVELOPMENT - W. F. Wilhite

'ECTIVE

The objective of this effort is the development of a gas chromatographic column :em as part of the gas chromatograph-mass spectrometer experiment capable of lyzing the atmosphere of Mars while on the surface of that planet.

:IVITIES DURING REPORT PERIOD

The contract with Dow Chemical was concluded successfully, resulting in the elopment of a column capable of resolving, in approximately 1 hr. at 25°C, most ne compounds of interest. These components have never before been separated ne column in gas chromatography. This achievement is the result of using the '-developed porous-polymer-bead column material. The latter provides a liquid-coated column giving high resistance to column deterioration -- as might aused by liquid coating migration.

The results of the Dow contract left a few unsolved problems, including no olution of nitrogen and carbon monoxide (which also cannot be resolved by the s spectrometer) and too long an analysis time (1 hr). Additional development PL resulted in the solution of these problems. This development involved the of a longer column and reduction of system dead volume to resolve nitrogen and on monoxide, and temperature programming to shorten the analysis time. The ılt is a gas chromatographic column which, when used in the gas chromatograph/ s spectrometer, will provide an analysis of the Martian atmosphere in less than nin. The components of interest that can be determined by this system are the owing: hydrogen, nitrogen, oxygen, argon, carbon monoxide, nitric oxide, hane, carbon dioxide, nitrous oxide, methyl fluoride, hydrogen sulphide, nonia, water, nitrogen dioxide, sulphur dioxide, and methyl chloride. It should oted that this list of components does not exclude the determination of other ponents of interest but presents a general capability of the system.

3LICATIONS DURING FY 1966

ers Presented at Meetings and Symposia

Wilhite, W. F., "Developments in Micro Gas Chromatography," presented at the 3rd International Symposium on Advances on Gas Chromatography, Houston, Texas, October 21, 1965.

:ansferred to Voyager Project in FY 1966.

Publications in the Open Literature

1. Bentley, K. E., Giffin, C. E., Whitten, D. G., and Wilhite, W. F., "A G Chromatograph-Mass Spectrometer System for Space Exploration," Analyti Instrumentation-1965, edited by Fowler, Harman, and Roe, Plenum Press, 1966.

2. Wilhite, W. F., "Developments in Micro Gas Chromatography," Journal of Gas Chromatography, 4, No. 2, 47-50 (1966).

JPL SPS Contributions

1. Wilhite, W. F., "A Micro Gas Chromatograph for Descent Analysis of the Martian Atmosphere," SPS 37-35, Volume IV, pp. 228-234.

JPL Technical Reports

1. Wilhite, W. F., Developments in Micro Gas Chromatography, JPL TR 32-8 March 1, 1966.

Final Contractor Report

1. Hollis, O. L., Separation of Gases by Gas Gell Chromatography at Room Temperature, The Dow Chemical Company, Final Report, May 5, 1966, Contract No. 951393.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

GAS CHROMATOGRAPHY-MASS SPECTROMETRY STUDIES - C. E. Giffin

OBJECTIVE

The long-range objective of this task is to develop a gas chromatograph-ma spectrometer (GC-MS) system capable of analyzing organic compounds found on surface of Mars. The immediate objectives are devising means through which t instrumentation can function automatically on a planetary surface. The problem be solved are those of:

1. Removal of GC carrier gas from the instrumentation.

2. Enriching sample components in the carrier gas stream.

3. Study of automatic operation and data handling of the combined GC-MS system.

PROGRESS

Studies of the removal of hydrogen carrier gas from the GC-MS system ha continued. Data taken to date indicate that sublimated titanium is indeed a feas approach for a pump. Efforts are presently being confined to methods for subli ing titanium at low power levels. Approximately 2000°C is required to sublime

significant quantities of titanium in a vacuum. Heated tungsten filaments require too much power. Therefore a palladium-aluminum combination (called Pyrofuse) is being investigated as a heat source. The Pyrofuse requires a temperature of only 660°C to initiate a tremendously exothermic reaction between the aluminum and palladium. The reaction is essentially gasless except for gases dissolved within the two materials. Figure 1 is a schematic drawing of tantalum sublimator vapor-coated with a thin shell of titanium. A capacitor discharge between the electrode and the body of the sublimator initiates the Pyrofuse braid which in turn initiates the Pyrofuse discs. The titanium coating on the external surface is then sublimated to the walls of a surrounding vessel where it reacts with hydrogen in the system and removes it from the system volume. A number of the sublimators in Fig. 1 are under construction and will be tested upon their completion.

A contract is being awarded to the University of Arizona to construct a prototype field ionization ion source. This ion source will preferentially produce only parent ions therefore simplifying the mass spectra of complex organic molecules. It is anticipated that a combination electron-bombardment-field ionization source will be the final outcome of this effort.

A series of misfortunes with the Nuclide Corporation in terms of late delivery and poor quality control in combination with the moving of the JPL mass spectrometry laboratory from the JPL Lake annex to the main facility has put the evaluation of sample enrichment devices sorely behind schedule. The Nuclide Corporation ion source for the JPL analytical mass spectrometer (ordered 1 yr ago) was finally delivered in apparently good working order June 1, and has been installed in the instrument. The testing of various types of enrichment devices will begin immediately.

The major task in the next six months will be the early phases of design and construction of a GC-MS breadboard instrument. The basic mass spectrometer is going to be a Nier-Johnson double-focusing instrument. It is sincerely hoped that a complete working breadboard involving sample pyrolysis, differential thermal analysis, and a tandem gas chromatograph-mass spectrometer will be completed by the end of FY 1967.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

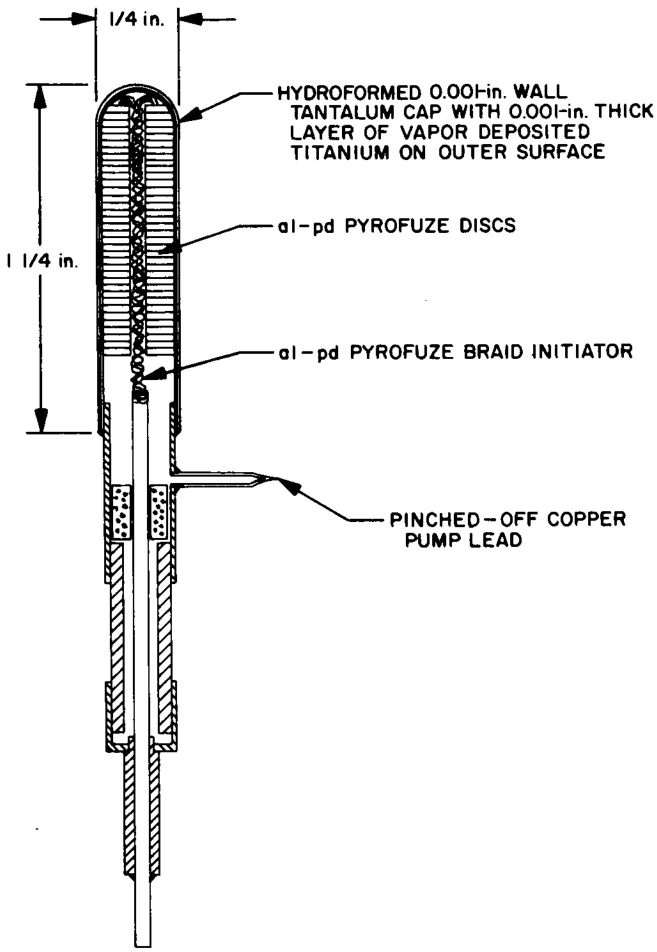


Fig. 1. Low power titanium sublimator

ULTRAVIOLET SPECTROMETER – SCIENCE SUPPORT

NASA Work Unit 185-37-26-12-55
JPL 383-32401-2-3280
C. A. Barth

)BJECTIVE

The objective of this task is to perform experimental research, explore heoretical background, and supervise instrument design of an ultraviolet spec-rometer operating in the 1000 to 4200 A region for planetary flyby spacecraft.

'ECHNICAL ACTIVITIES

Active work on this work unit ended in late 1965.

C. A. Barth has proposed UV Spectrometer experiments for Mariner 69 and 'oyager based on the developments accomplished under this and related tasks over he past several years.

This task terminated at the end of FY 1966.

'UBLICATIONS DURING FY 1966

PL Technical Reports

. Barth, C. A., Ultraviolet Spectroscopy of Planets, JPL TR 32-822, December 15, 1965.

'UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

INFRARED SPECTROSCOPY OF SYNTHETIC ATMOSPHERES

NASA Work Unit 185-37-26-16-55
JPL 383-32801-2-3250

J. M. Flournoy

OBJECTIVE

The aim of the work unit is to provide laboratory absorption spectra in the visual and near infrared regions of gases which are of interest because they do occur, or may occur, in planetary atmospheres.

PROGRESS

The measurements are being made in the JPL Spectroscopy Laboratory and Absorption Tube Facility. The installation provides optical paths in the absorbing gas up to 1 km long, using two multiple reflection cells of the White type. Spectra are taken with either a 1.8-m Ebert scanning vacuum spectrometer or a 5-m Fastie photographic vacuum spectrograph.

During the period since the last semiannual progress report, the above apparatus and a commercial 1-m White cell capable of 40 passes have been installed and made to work. Using the small cell and 1.8-m spectrometer, high-resolution spectra have been obtained of the 1.6 and 2.0 μ bands of CO_2 and the 1.6 μ bands of CH_4 and CH_3Cl, as well as bands occurring at 1.6 μ in the spectra of mixtures of CO_2 and H_2S in various proportions. (Figure 1 shows the spectrum of methyl chloride.) Also, using the small spectrometer and a single-pass 10-cm cell, the spectrum of methane at 1.6 μ was traced with improved signal/noise. These measurements were made with a resolution of 0.1 cm^{-1}, with the aim of comparing them with high-resolution planetary spectra obtained with the Connes' interferometer. The work is continuing with the hope of using improved and cooled detectors to increase the signal-to-noise ratio, and hence the available resolution.

In addition it has proved possible to use the 6-m White cell at ambient temperature with pressures of up to 15 atmospheres and path lengths up to 1.1 km. This is greater than the design requirements; the path length has been increased by resurfacing the mirrors, substituting silver for aluminum, and holding the reflectivity constant by maintaining either a reducing atmosphere or a low pressure inside the cell. With this cell and the 5-m spectrograph the relatively weak band in the spectrum of methane at 0.62 μ has been photographed with a resolution better than 0.04 cm^{-1}. This band has been observed in the spectra of the outer planets, and our measurement may help in using the line shapes as tools for probing the structures of their atmospheres. This band has not previously been analyzed, and this will be attempted.

It is hoped to use a similar technique to observe the CO_2 band at 0.87 μ, which has been measured in the Cytherean spectrum. We are presently using the apparatus to search for the quadrupole lines of molecular hydrogen, which have been detected in the spectra of the outer planets.

Experiment and theory have strongly suggested that any attempt to extend the operating temperature range of the large White cell as it is presently mounted would be costly and time-consuming. We will proceed with ambient temperature spectroscopy with it in its present form.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

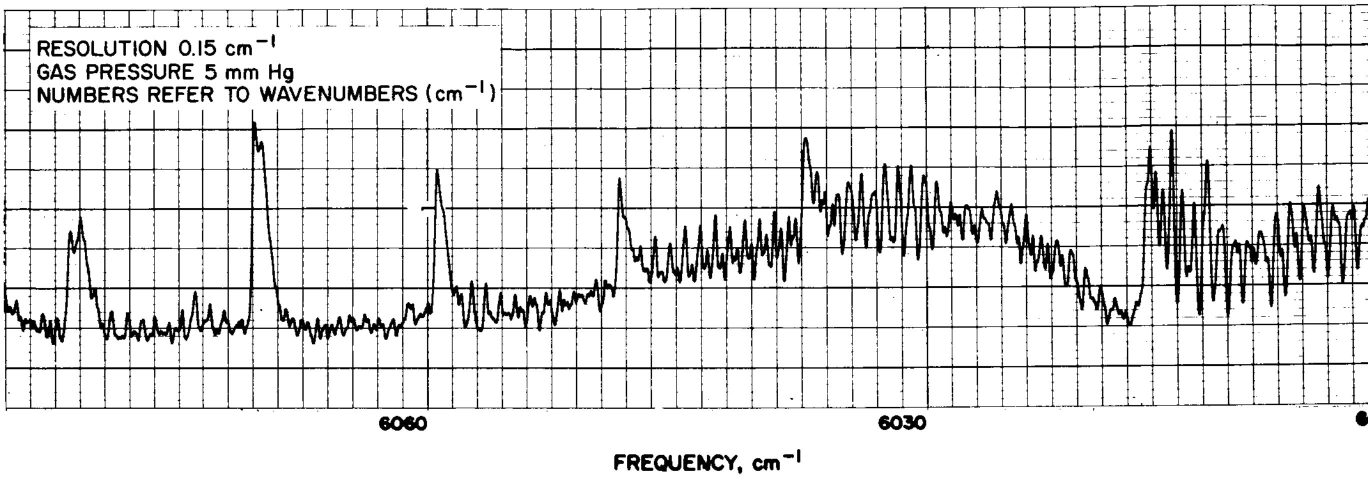


Fig. 1. Methyl chloride spectrum (taken on 1.8-m spectrometer, using 1-m White cell at 40 passes)

IONOSPHERIC AND RADIO PHYSICS (185-39)

MICROWAVE SURFACE PROPERTIES STUDY

NASA Work Unit 185-39-05-01-55
JPL 383-90101-2-3250

W. E. Brown, Jr.

)BJECTIVES

The long-range objective of this study is to provide microwave instrumentation ınd data interpretation techniques for the study of planetary surfaces. The objectives or FY 1966 were (1) to obtain factual information about the radar echo behavior as a ınction of altitude for altitudes up to 150 km and (2) to reduce the ambiguities in echo ıterpretation by obtaining the echoes from a target area with known and measurable haracteristics.

'IELD OPERATIONS

The L-band radar was successfully flown on the Convair 990 April 27, and the erobee 150 on May 9, 1966. Echoes were obtained from the Tularosa basin area in ew Mexico from altitudes of 5, 10, and 80 to 166 km. Consequently, the first objecve has been accomplished.

For the second objective, the penetration of the transmitter pulse into the ırface was measured by instrumentation buried at depths of 6, 3, and 1 ft for the onvair 990 flight and 3, 1, and 0 ft for the Aerobee 150 flight. Samples of the terain were taken from 22 separate sites scattered over the radar target area.

ABORATORY EXPERIMENTAL STUDIES

The field samples were returned to the laboratory where measurements of ater content, void ratio, mineral content, grain-size distribution, and electrical ırameters are being made. The flight systems are currently being given additional)stcalibration tests. The flight-data reduction will begin as soon as the special luipment that has been requisitioned arrives at JPL. The equipment was not proured until the data were obtained. An engineering report on the flight equipment nd operations is now being written. A sample holder for reflection and emission tudies is being constructed. Correlation of theoretical and experimental behavior f surface layer electrical and thermal effects will be measured during the next six ıonths.

'HEORETICAL STUDIES

A theoretical model of the dispersion of incident power by an irregular surface s being developed. The distribution of scatterer sizes is being derived for the ınar surface from the wavelength dependence of the radar reflections.

URVEYOR RADAR DATA ANALYSIS

The signal strength information from the Surveyor I radar data has been nalyzed in preliminary form. Radar cross sections of about 0.05 for the 25-deg ff-normal beams and 0.02 for the vertical beam have been derived. The relative ermittivity deduced from these values of cross section falls between 2.6 and 3.0.

These values of radar cross section are consistent with those predicted from Earth-based radar measurements.

FUTURE ACTIVITIES

The field operations for FY 1967 include additional Convair 990 flights over various surfaces and two Aerobee 150 flights. One of the Aerobee flights may carr a 30-ft inflatable antenna, which is currently under a feasibility study. This antenr would allow the radar system to provide a low-resolution map of the southwestern United States as well as reflectivity data in both polarizations. The laboratory wor on the instrumentation will include the development of a coherent L-band radar sys- tem and a continuing effort on cataloging of the Tularosa basin sample measuremen

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

ASTRONOMY (185-41)
OPTICAL ASTRONOMY

NASA Work Unit 185-41-21-01-55
JPL 383-10201-2-3250

Ray L. Newburn, Jr.

BJECTIVES

All available techniques of ground-based optical astronomy will be used to study
ie bodies of the solar system in order to furnish the best possible description of the
urfaces and atmospheres of those bodies to engineers for spacecraft design and to
ngineers and scientists for experiment design.

QUIPMENT

The new 24-in. Cassegrain-Coudé reflector was installed during March (Fig. 1
nd 2). Alignment and operational tests were carried out during April, and the first
ormal observations were begun at Cassegrain focus with a photoelectric photometer
ı May. Conceptual designs, including critical dimensions, were completed for a
oudé room and dark room by R. Newburn and R. Norton, and formal architectural
nd engineering drawings were begun for these structures immediately upon their
pproval by NASA headquarters in May. The present schedule calls for beneficial
ccupancy of the Coudé room by September 15 and completion of all construction by
ovember 1. Approval has been received for the construction of a rising observation
oor. This will be carried out during the next six months.

The photoelectric photometer originally designed for the 16-in. reflector has
een adapted for use at the 24-in. reflector by E. Miner and is in use there now. An
xisting 1-m Ebert scanning monochromator is being adapted for use at the 24-in.
assegrain focus by J. Gunn. The completed system of monochromator and elec-
ronics should be in operation by November. The Mark III Connes-type Fourier
pectrometer under development by R. Beer will be installed in the Coudé room
nmediately upon our gaining beneficial occupancy. A very sophisticated new plane-
ıry camera for use at the 24-in. Coudé focus is being designed by E. Dobies and
ill be in operation before the end of the year.

The optical design for a single-camera high-dispersion Coudé spectrograph
A/mm dispersion) has been completed by R. Norton, J. Gunn, and R. Newburn,
ith a complete set of ray-traces computer-programmed and evaluated by Norton
nd Gunn. Approval to construct the instrument has been requested of NASA
eadquarters.

TERNAL OBSERVING PROGRAM

The thousands of observations made during the 1964-65 Mars patrol by
. F. Capen have now been reduced. A formal report has been completed and is
urrently being edited for publication as a JPL TR. A new Mars patrol covering the
966-67 apparition will begin in November.

A report on the many observations of Comet Ikeya-Seki made during October
ıd November 1965 has been delayed until completion of the Mars patrol report.

Reduction of the comet data is now actively under way and the formal report will be written this fall.

The lunar patrol effort has been sporadic due to equipment problems. No pos tive results have been obtained to date. It is anticipated that past difficulties will b overcome shortly.

A fairly regular photographic patrol of Venus has been carried out for severa months with the 16-in. reflector. This will be continued in anticipation of the Mariner 1967 flight to Venus. Theoretical work under way by R. Norton on the sca tering of radiation in a spherical geometry will hopefully give guidance in the inter- pretation of the photographic results.

A program of photoelectric photometry of the rings and satellites of Saturn is being carried out at the 24-in. reflector by E. Miner during this critical year when the Sun and Earth pass through the plane of the rings. This celestial geometry will not be repeated for 15 yr.

A large number of programs are planned for the 24-in. reflector as the facili comes into full operation. These include a search for nitrogen on Venus by J. Gun precision photographic spectrophotometry of the Moon by J. Adams and E. Dobies, high dispersion infrared (1 to 2μ) Fourier spectrometry of the planets by R. Beer, and planetary and satellite photometry by E. Miner.

EXTERNAL OBSERVING PROGRAM

R. Younkin has continued with the reduction of spectrophotometric data taken during the period 1962-65 at the Mt. Wilson 60-in. reflector. Papers based upon t are listed at the end of this work unit. Younkin anticipates beginning a new progra on Saturn in July and on Mars in December. The latter is particularly important, adequate photometric functions are to be available in time for the Mariner 1969 Ma mission.

R. Schorn and L. Gray have obtained a number of excellent new high-dispers infrared spectra of Venus with the 82-in. Struve reflector at McDonald Observator These are undergoing reduction. Schorn is continuing the search for any atmos- pheric constituents on the Galilean satellites of Jupiter, at times making use of the new Carnegie image converter. Schorn will begin a new program of study of Marti water vapor at McDonald Observatory in December.

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

1. Younkin, R., and Munch, G., "Visible and Near Infrared Spectrophotometry Saturn's Rings," American Astronomical Society, December 27-30, 1965.

2. Schorn, R., "The Atmosphere of Mars," AIAA Specialist Meeting, February 1966.

3. Capen, C., "Observational Features of Mars," AIAA Specialist Meeting, February 8, 1966.

4. McClatchey, R., and Norton, R. H., "Atmospheric Sensing with CO_2 Lasers," Remote Electromagnetic Sensing Symposium, November 1965.

5. Younkin, R., "A Search For Limonite Near-Infrared Spectral Features on Mars," Joint Caltech-JPL Lunar and Planetary Conference, September 13-18, 1965.

6. Capen, C., "The Mars Patrol in Support of Mariner IV Space Mission," Morrison Lecture, Redlands University, October 28, 1965.

7. Capen, C., "The Planet Mars," Scientific Research Society of America Meeting at Lockheed Propulsion Division, November 11, 1965.

Publications in the Open Literature

- Spinrad, H., Pyper, P., Newburn, R., and Younkin, R., "Further Studies of the Infrared Spectra of Cool Stars, The Water Deficiency in S Stars and the Variation of Water Abundance with Mira's Phase," Astrophysical Journal, 143, 291-298 (1966).

- Younkin, R., "A Search For Limonite Near-Infrared Spectra Features on Mars," Astrophysical Journal, 144, 809-818 (1966).

- Spinrad, H., and Younkin, R., "Infrared Bands of Vanadium Oxide in Three Mira Stars," Publication of the Astronomical Society of the Pacific, 78, 65-67 (1966).

- Aller, L. H., Faulkner, D. J., and Norton, R. H., "Photoelectric Spectrophotometry of Selected Southern Stars," Astrophysical Journal, 144, 1073-110 (1966).

JPL SPS Contributions

- Young, J. W., "Aristarchus Observations," SPS 37-34, Vol. IV, pp. 183-4, August 31, 1965.

- Capen, C. F., Jr., "Mars Patrol 1964-65," SPS 37-34, Vol. IV, pp. 184-7, August 31, 1965.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

Publications in the Open Literature

- Spinrad, H., Schorn, R. A., et al., "1964-65 Spectroscopic Observations of Mars. I: The CO_2 Content and Surface Pressure," Astrophysical Journal (accepted for publication, November 1966).

- Schorn, R. A., Spinrad, H., et al., "1964-65 Spectroscopic Observations of Mars. II: Water Vapor," accepted by Astrophysical Journal for February 1967 publication.

3. Schorn, R. A., "Storing Ammoniated Infrared Emulsions," Publication of the Astronomical Society of the Pacific (accepted for publication in 1966).

4. McClatchey, R. A., and Norton, R. H., "Atmospheric Sensing With CO_2 Lasers," to be published in Proceedings of the Remote Electromagnetic Sensing Symposium by Academic Press.

5. Schorn, R. A., Encyclopedia of Earth Sciences, chapters about Venus and Mars, Reinhold Press, 1966.

6. Gunn, J., "A Diffusion Model for the Martian Atmosphere," to be submitted f publication in a few weeks.

7. Younkin, R., "Spectrophotometry of Uranus," to be submitted for publication a few weeks.

8. Spinrad, H., and Younkin, R., "Titan and the Galilean Satellites of Jupiter," be submitted for publication in a few weeks.

9. Younkin, R., "Spectrophotometry of Jupiter and Saturn," data reduction well along.

JPL Technical Reports

1. Capen, C. F., The Mars 1964-65 Apparition, has been submitted to JPL reports group for editing and publication.

2. Gunn, J., "Photon Noise in Fourier Spectroscopy," paper completed and in final stages of rewrite.

3. Capen, C. F., and Young, J., "The Morphology of A Great Comet, Ikeya-Sel 1965f," data reduction proceeding well.

Fig. 1. 24-in. reflector

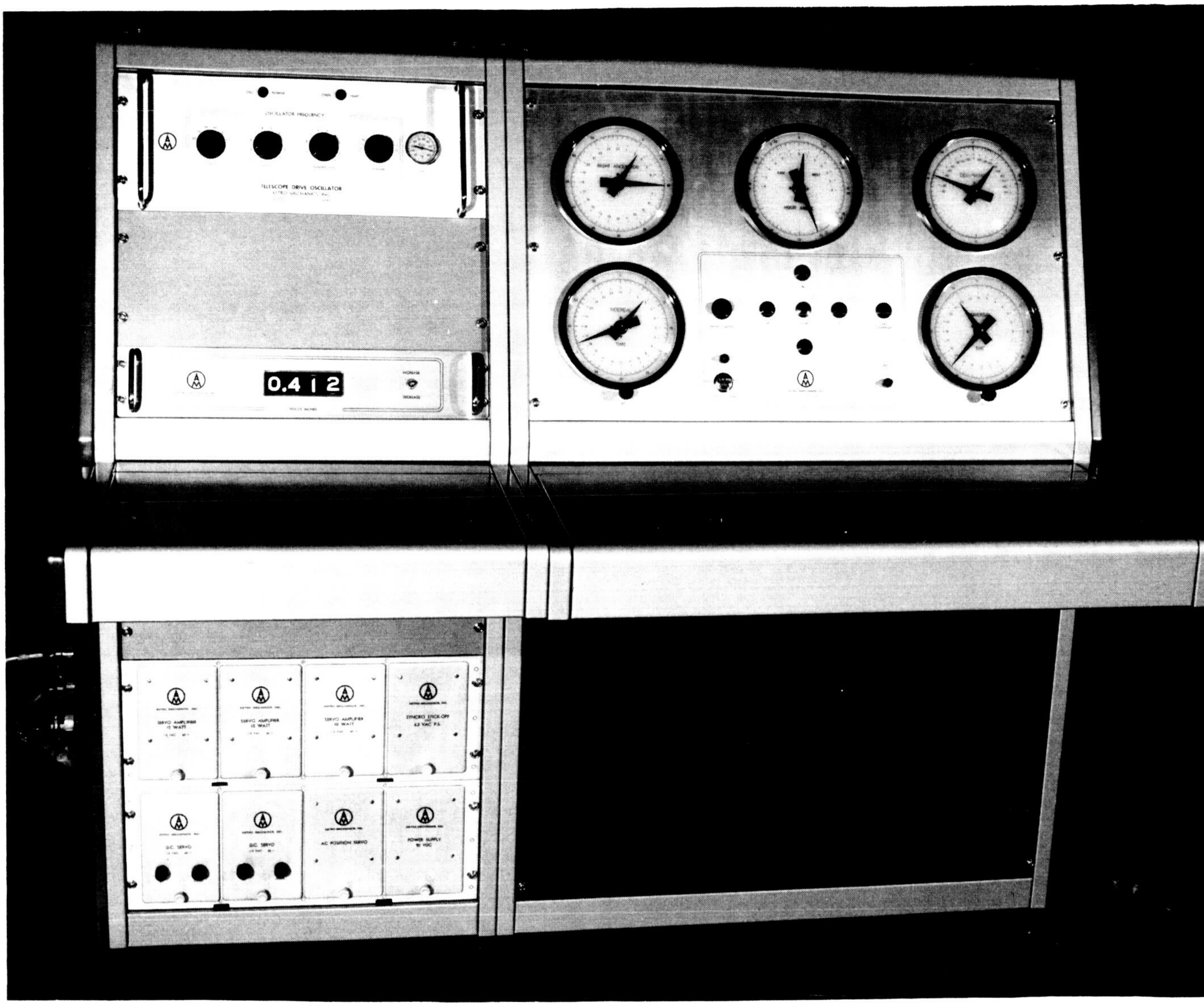


Fig. 2. Control console of the 24-in. reflector

RADIO ASTRONOMY
NASA Work Unit 185-41-21-02-55
JPL 383-10301-2-3250
R. L. Carpenter

)BJECTIVE

The objective of the radio astronomy program is to increase our understanding ›f the Moon and nearer planets by means of (1) passive radio astronomy at centi-neter and millimeter wavelengths and (2) ground-based radar observations. In ›articular, programs have been or are under way (1) to determine accurately the ransition region in Venus' microwave spectrum in the region of 13.5 mm, (2) to neasure the brightness temperature of Jupiter in the region of the NH_3 band at 2.5 mm, (3) to radiometrically map the Moon at 3.3 mm, (4) to investigate the ›roblems associated with the construction of an 8- to 13-mm interferometer, and 5) to study Venus by ground-based radar (in the near future Mercury and possibly the Moon will be included).

'ENUS MICROWAVE OBSERVATIONS

From July 3 through July 19, 1964, Venus was observed at eleven frequencies etween 20.6 and 24 GHz. The observations were made using the 30-ft dish at Gold-tone. The results were presented in the preceding semiannual progress report. In ummary, a broad minimum centered between 21.5 and 22.0 GHz is suggested as 'ell as the possibility of fine structure. The water line may have been observed in mission. There was also a suggestion that the brightness temperature at 22.23 GHz aries with time. When both the 2800 MHz solar flux and the Venus data are cross-orrelated versus date, a strong correlation results with a lag of between 1 and days.

An observational program was undertaken during the 1966 Venus conjunction to btain more data on both the solar flux relation and the variability of the microwave pectrum. Observations were conducted on a daily basis using the 30-ft dish at ·oldstone between February 6 and April 17, 1966.

A very preliminary analysis of the data suggests a brightness temperature pectrum that is time variable. During the first month, the average spectrum ppears approximately flat in the region from 21 to 22.5 GHz. After this time the pectrum exhibits a pronounced peaking at a near 22-23 GHz (i.e., over the interval :om 22.0 to 22.5 GHz) and near 23.0 GHz, while at $\nu \leq 21.5$ GHz T_B remains rela-vely constant throughout the observing period. Observations of the Sun, Moon, and 'aurus A were also made. A check of the computed spectrum of the Moon shows it to e flat within ~ ± 5% over the frequency interval observed.

UPITER MICROWAVE OBSERVATIONS

During December 1964 and January 1965, Jupiter was observed at 23.445, 3.900, and 24.005 GHz near the NH_3 band; the brightness temperatures obtained ere 111, 144, and 134°K, respectively. The relative probable error between these alues was about ±6°K. A very weak but positive correlation with solar activity was ›und for two of the three frequencies with a lag of about 12 days. The observations

need repetition; however, due to manpower limitations no observations are being planned during Jupiter's 1966 opposition.

TABLE MOUNTAIN RADIO OBSERVATORY

A concerted effort was made to bring the Radio Astronomy Facility at Table Mountain into operational condition. The purposes of this effort were:

1. To prepare the site as nearly as possible for the 18-ft-diameter millimeter wave dish to be installed in the early spring of next yea Extensive observations were made so that the polar axis of the antenna pedestal could be aligned accurately.

2. To check out, using celestial objects, the characteristics of the 19-25 GHz radiometer that is being used on the 30-ft dish at Goldstone for observing Venus in 1966.

3. To optimize the operational techniques to be utilized during the 1966 Venus observing program at Goldstone.

MOON MILLIMETER OBSERVATIONS

Observations of the Moon at 3.3 mm were made in FY 1964 in a joint effort between JPL and the Aerospace Corporation using their 15-ft dish. The antenna bea width was 2.9 ft. This allowed the construction of high angular resolution maps of the 3.3-mm thermal radiation of the Moon. The analysis showed that the maria ar warmer than the mountains by 2.6 ± 0.2°K averaged over a lunation, which is large than the 0.8°K value expected from albedo considerations. The first report of the results has been published in the Astrophysical Journal Supplement No. 108, December, 1965.

Analysis of the data has continued in an attempt to learn more about the lunar surface. The observed microwave temperature variation during a lunation has bee compared with predictions based on a model for the lunar surface which allows for the existence of vertical and horizontal inhomogeneities of important parameters o the lunar material (density, thermal conductivity, specific heat, and microwave absorption coefficient). Values for these parameters were subjected to constraints imposed by infrared observations of the lunar nighttime surface temperature. It w found that no combination of parameter values permitted by the infrared constraint could account for the microwave observations. This demonstrates the need for a more sophisticated model, and it is suggested that some provision should be made for a temperature dependence of the lunar material's thermal conductivity and specific heat.

3.2-mm MERCURY AND VENUS OBSERVATIONS

In October a new program was initiated between JPL and the Aerospace Corporation using their 15-ft dish to observe Mercury and Venus at 3.2 mm. Initi observations of Mercury appear to confirm Aerospace's previous results that the planet is cold (200°K) and shows no phase variations. The Venus observations that have been made to date have not yet been reduced.

COMET IKEYA-SEKI OBSERVATIONS

The tail of Comet Ikeya-Seki was observed at 14.56 mm using the 10-ft dish at [able Mountain. Since the width of the tail filled the 1/3 deg beam of the antenna, the neasurements are a very sensitive test for microwave emission. No radiation was letected. The brightness temperature of the tail must have been less than 0.06°K ıbove the sky background.

- to 13-mm INTERFEROMETER

Discussions have been underway between the Radio Astronomy group and the Radio Science group on problems associated with an 8- to 13-mm interferometer. It s hoped that within the next 6 to 9 months an interferometer can be set up, possibly n Table Mountain, using the 10- and 18-ft dishes. This will be an experimental nodel to be used to obtain engineering information. It will be useful for the design f a larger facility which may possibly incorporate two of the 30-ft dishes at Goldstone.

'ENUS CW RADAR OBSERVATIONS

The results indicate that the polarized and depolarized reflectivities are .114 ± 0.01 and 0.0067 ± 0.0005, respectively. They lead to an average dielectric onstant of the surface of 3.75 ± 0.3. The bandwidth data, taking into account posible systematic errors, indicate a sidereal period of 250^{+4}_{-7} days retrograde. The orth polar axis is pointed toward $\alpha = 255°^{+10°}_{-40}$, $\delta = 68° \pm 4°$. The obliquity of 'enus' axis to its orbit pole is about 7 deg. Possible identification of the 1964 surace features with those observed in 1962 indicates the period may be near 244 days etrograde.

Venus was observed again during its 1966 conjunction. A completely revised pectral analysis program was employed that utilized special purpose equipment built y the Telecommunications Division and located at Goldstone. This resulted in a aving of about a factor of 10 in IBM 7094 computer time. Observations were made rom early November 1965 to the middle of March 1966. Conjunction occurred anuary 26, 1966. Both polarized and depolarized spectra were obtained. They show eatures similar to those observed in 1962 and 1964, and a comparison of their notions over the three successive conjunctions suggests that Venus' sidereal period s remarkably close to 243.16 days retrograde. With this period Venus would preent the same face toward the Earth at every conjunction. Further analysis of the adar data is proceeding.

'UBLICATIONS DURING FY 1966

'apers Presented at Meetings and Symposia

. Carpenter, R. L., "Venus Radar Observations," Gordon Research Conference, July 1, 1965.

. Carpenter, R. L., "Preliminary Results of the 1966 Study of Venus by CW Radar," USNC/URSI meeting in Washington, D. C., April 19, 1966.

Jones, D. E., "Observations of Venus at 1.35 cm," Caltech-JPL Lunar and Planetary Conference, September 16, 1965.

Publications in the Open Literature

1. Carpenter, R. L., "Study of Venus by CW Radar-1964 Results," Astronomica Journal, 71, March, 1966.

2. Carpenter, R. L., Muhleman, D. O., and Goldstein, R., "A Review of Rada Astronomy," IEEE Spectrum, October and November 1965.

3. Gary, Bruce, Stacey, J., and Drake, F. D., "Radiometer Mapping of the Moo at 3-Millimeters Wavelength," Astrophysical Journal Supplement No. 108, November, 1965.

JPL SPS Contributions

1. Jones, D. E., "Observed Venus Microwave Brightness Temperature in the Wavelength Interval 1.25-1.45 cm," SPS No. 37-36, Vol. IV, p. 208, December 31, 1965.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

PLANETOLOGY (185-42)
PETROGRAPHIC STUDIES

NASA Work Unit 185-42-20-02-55
JPL 383-20201-2-3250

A. A. Loomis

)BJECTIVE

The long-range program objective is to develop a remotely operating etrographic microscope for use in exploration of the Moon and planets.

The objective for FY 1966 and FY 1967 is the design, fabrication, and environ- ental testing of an engineering prototype model of the instrument.

ARTICLE-SEPARATOR DEVELOPMENT

The sample is an aggregate of rock and mineral particles. These are delivered o the microscope and pumped into a hopper. The hopper is required to separate the articles according to size, and to deliver those separates to a thermoplastic for ncapsulation.

As the first phase of Contract 951273 (let to Electro-Optical Systems, Inc.) OS fabricated and tested the hopper shown in Fig. 1. The hopper oscillates ± 1 cm bout an axis at its right-hand end. The particles are thrown by centrifugal acceler- tion against the screens. At 20 Hz, the peak centrifugal acceleration is about Moon g. After separation is complete, ports open above the separate compart- ents, and the particles are thrown vertically onto the surface of a heated thermo- lastic sheet. The peak vertical acceleration is about 30 Moon g at 20 Hz.

EOS demonstrated the mechanism in vacuum ($\sim 10^{-7}$ torr) for JPL on anuary 7, 1966. During that test, particle separation was fair and the density of articles embedded in the thermoplastic was fair to poor. The general method was onsidered successful, however. Consequently, further work has been conducted at PL to improve the technique.

Allen Ford of JPL Section 356 designed the hopper shown in Fig. 2 and 3. The opper can be inclined so that the particles impinge on screens which are inclines; he particles are thrown against the screens with components of both the vertical cceleration and the centrifugal acceleration. A series of tests which is still under ay at this writing shows that the best separation occurs when the screens are near 5 deg as shown in Fig. 2. That separation is perfectly adequate for the purposes of he experiment. Particle encapsulation experiments are also under way at this riting; they have been quite successful to date.

A third-generation particle-separation hopper is being designed to incorporate he best features of previous models. It will be in flight configuration. Fabrication nd final testing should be complete by July 15, 1966.

)VERALL PROGRESS

In addition to the particle-separator development, EOS performed detailed ptical design for air-gapped lenses of 40× and 100× magnifications; they also

produced a detailed layout design of an engineering prototype model microscope. Th optical design is good. The layout designs for the entire microscope were not approved, however.

The main considerations in disapproving the EOS instrument design were that the instrument would weigh nearly 20 lb, that the mechanical motions would be too cumbersome, and that there was a large chance that some of the methods by which moving parts were to be scaled would fail.

Rather than redirect EOS in a new design, the contract was terminated. Further design work is being conducted at JPL by Mr. Ford. The results of the preliminary design work are most encouraging. A milestone chart is given as Fig. 4. Solid bars have been completed; the other tasks are in progress.

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

1. Loomis, A. A., "A Lunar and Planetary Petrographic Microscope," Geological Society of America Annual Meeting, November 1966.

JPL Technical Reports

1. Loomis, A. A., A Lunar and Planetary Petrography Experiment, JPL TR 32-785, September 1965.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

Publications in the Open Literature

1. Loomis, A. A., "A Lunar and Planetary Petrography Experiment," to be submitted about December 1966, journal undecided.

JPL SPS Contributions

1. Loomis, A. A., "Particle-Separation Mechanism Development," in preparation.

2. Loomis, A. A., "Thermoplastic Properties," to be written about fall, 1966.

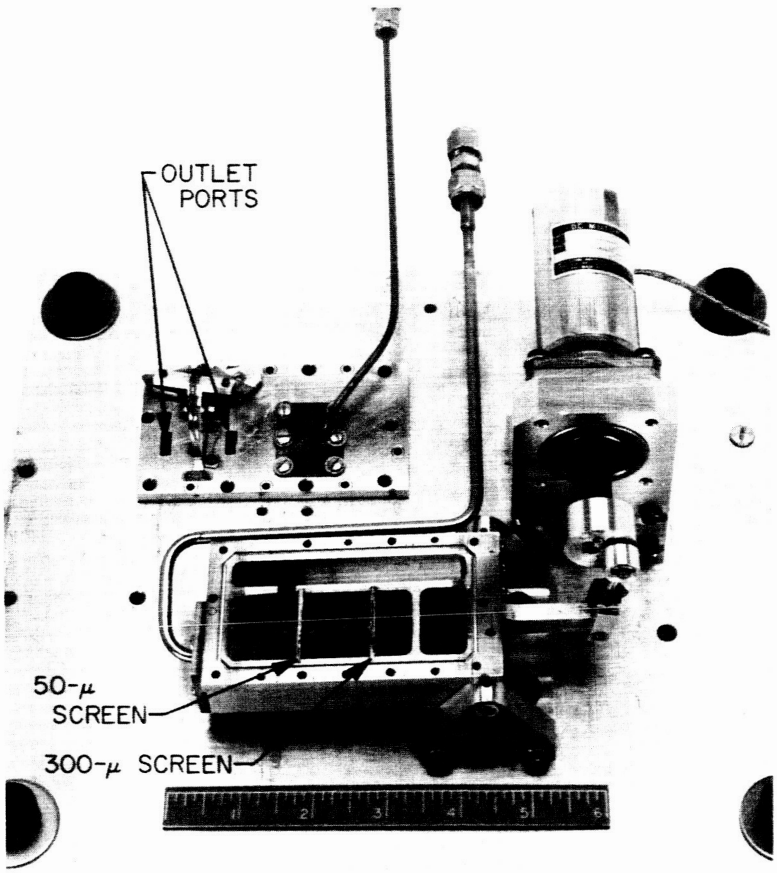


Fig. 1. EOS-designed hopper

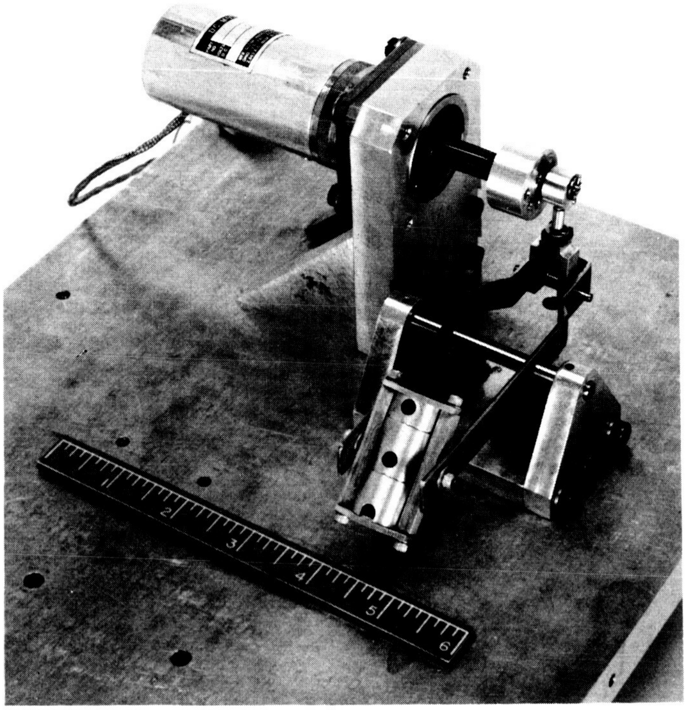


Fig. 2. JPL-designed hopper

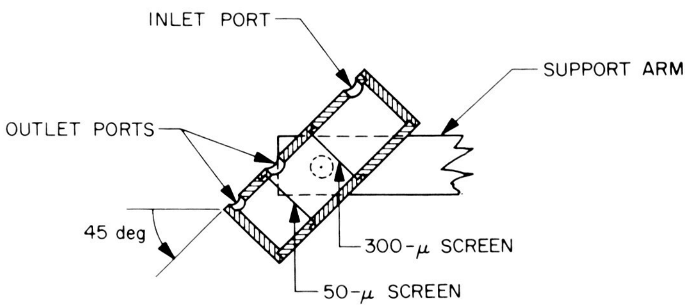


Fig. 3. Schematic for JPL-designed hopper

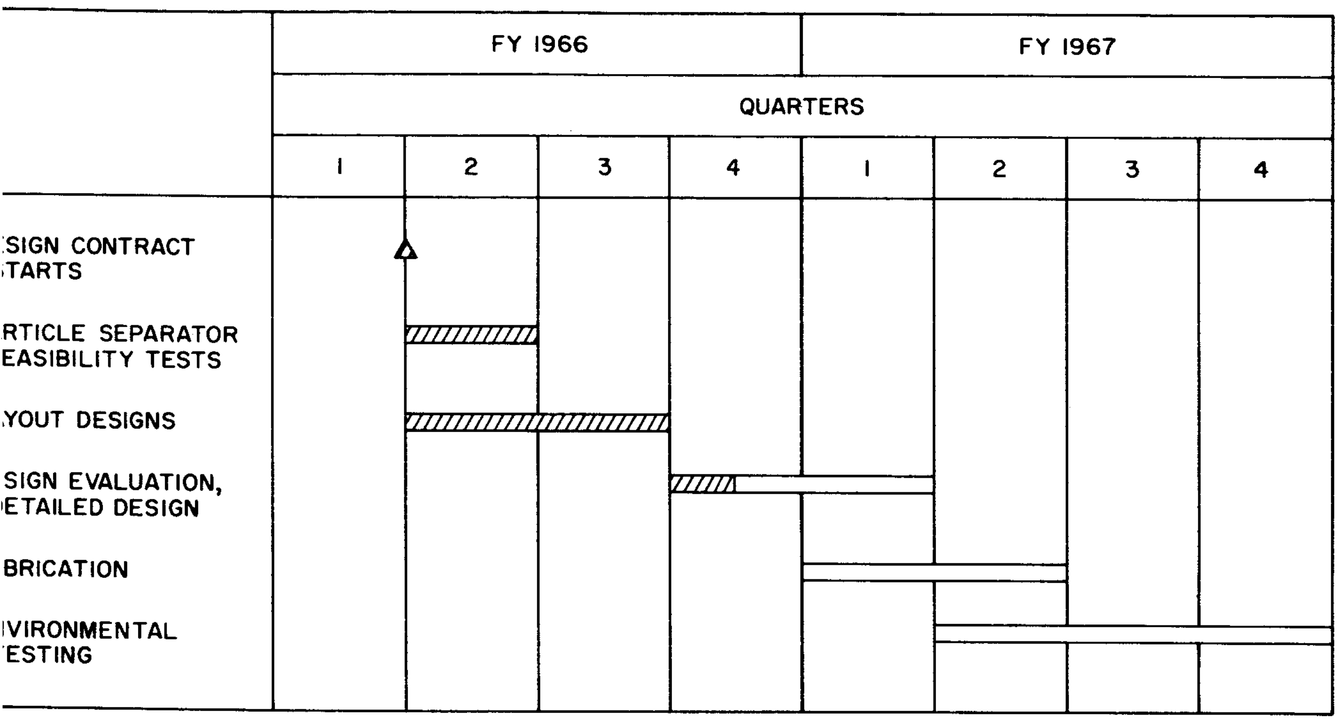


Fig. 4. Milestone chart for petrographic studies

INFRARED EMISSION FROM SILICATES
NASA Work Unit 185-42-20-20-55
JPL 383-20501-2-3250

J. E. Conel

)BJECTIVE

Infrared emission spectroscopy in the 8 to 40μ region is under investigation as ne method for remote compositional analysis of planetary surfaces. The principal bjectives of this year's program have been to construct a high-sensitivity, large-ield-of-view portable spectrometer for examination of terrestrial surfaces in the to 14μ region and to use this instrumentation in the field. In addition, a program of efined laboratory emission measurements was begun.

'ORTABLE SPECTROMETER

This system (Fig. 1 and 2) was successfully operated for the first time on ,pril 26, 1966. A rough wavelength calibration was carried out using polypropylene, olystyrene, and mylar thin films. Emission spectra of a granite slab were taken at arious slit widths and the sample at a temperature of 320°K. These compared avorably with reflection spectra obtained with our standard laboratory spectrometer.

The detector used in this application is cadmium-doped germanium, which ecomes background limited at 20°K. This operational temperature is attained in our ase with an Arthur D. Little (ADL) helium refrigerator. Use of the refrigerator for etector cooling had never before been attempted and, as would be expected, some ovel problems have arisen. The refrigerator has a 1.2-Hz reciprocating pump 'hich gives rise to 30-Hz mechanical vibration and 1.2-Hz temperature cycling of bout 1°K amplitude at its lowest attainable operating temperature (13 to 14°K). We ave effectively eliminated detector temperature variation by a partial thermal isola-on of the detector from the cooling head and by adding thermal mass (copper disk) round the detector. Mechanical vibrations allow the detector to view a variable ackground external to the vacuum chamber. It is curious that variations in detector utput arising from vibration are strongly enhanced by allowing the detector to view self in a mirror, but disappear entirely when a diffuse background is inserted in the eam. We consider that microphonics can be greatly reduced by proper rigid attach-ıent of the refrigerator unit to the walls of the vacuum chamber.

The ADL unit promises to be a reliable method for detector cooling in the emperature region above about 13°K. In our application it offers the advantage of liminating the need for liquified gas storage and transport and of providing long term ıp to 2500 hr) intermittent (or continuous) operation without servicing.

A reduction from 2 to 1 in the number of technical personnel working on this roject occurred on April 1. This has increased the time required for completion of pectrometer construction and has delayed our laboratory program as well.

The immediate future plans for this phase of the project include bringing the ortable spectrometer to operational readiness and carrying out wavelength and otometric calibrations. A systematic procedure for determination of instrument ansmission functions and background has been worked out and construction of the ecessary calibration facilities begun.

LABORATORY PROGRAM

During the year an improved sample furnace and conical blackbody reference cavity were constructed (Fig. 3, 4, and 5). Both are designed to operate in the temperature range 25 to 250° C ± 1° C. The top surfaces are gold-plated copper she and are water cooled.

The blackbody radiator (Fig. 5) is an aluminum cone of 24 deg semiangle. It uniformly heated by Nichrome wire wound in threads on the outside of the cone. Al surfaces of the cone are anodized to increase emissivity and provide electrical ins lation. Construction of this unit followed rejection of a razor blade blackbody as a suitable radiation reference because of the strongly polarized state of the light emitted from such devices.

Two additional pieces of laboratory equipment were obtained during the year. A precision radiometer (Huggins Model, Mark IX) equipped with 6 spike filters and an 8 to 16μ interference filter was obtained. It has been and will be used for constructing detailed thermal maps of laboratory samples, and in field work for sourc temperature determination.

Secondly, the Beckman IR-7 spectrophotometer was equipped with a digitizer and high-speed paper tape punch. A computer program for the IBM 7094 has been written which will allow computer reduction of all spectrophotometric data taken wi this machine. Eventually the program will be expanded to include graphical printo of absorption, reflection, or emission data and computation of infrared absorption coefficients and refractive indices from reflection measurements.

THEORETICAL

A brief analysis of spectral effects produced by target thermal nonuniformity was made. Specifically we investigated whether maxima and minima could be intro duced in a curve of spectral emissivity of even a "black" surface simply because o nonuniform source temperature. The tentative conclusion reached is that the exist ence of extreme values in the apparent spectral emissivity of a black, but thermall nonuniform surface depends upon the condition

$$\int_{\text{Source Area}} \left[\frac{T_R}{T(x, y)} - 1\right] \exp\left[-\frac{c}{\lambda T(x, y)}\right] dxdy = 0,$$

where T_R is a constant reference temperature, $T(x, y)$ the temperature at point (x, y), λ the wavelength, and c a constant. Aside from the case $T_R = T(x, y)$ for al (x, y), it appears likely that some function $T(x, y)$ can be found which satisfies this condition. The analysis suggests that all such spectral difficulties can be mathematically avoided by judicious choice of the reference temperature T_R, such that t factor

$$\left[\frac{T_R}{T(x, y)} - 1\right]$$

is either positive or negative for all (x, y).

:EETINGS ATTENDED, TALKS PRESENTED

October 27, attended IRIS Specialty Group Session on Infrared Backgrounds and Atmospheric Physics, oral presentation of laboratory studies.

January 11-13, attended NASA/OSSA/SM infrared team meeting in Menlo Park, California. Proposal for Earth-orbiting infrared experiment was prepared jointly with R. J. P. Lyon and others and submitted to NASA on April 4, 1966.

March 14-16, attended University of Nevada conference on test sites, presented a discussion on description of test sites for remote sensing experiments.

December 1965, became a member of the Surveyor Working Group on Lunar Thermal Properties, which is responsible for scientific interpretation of thermal sensor data from Surveyor spacecraft.

JBLICATIONS DURING FY 1966

None.

JBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

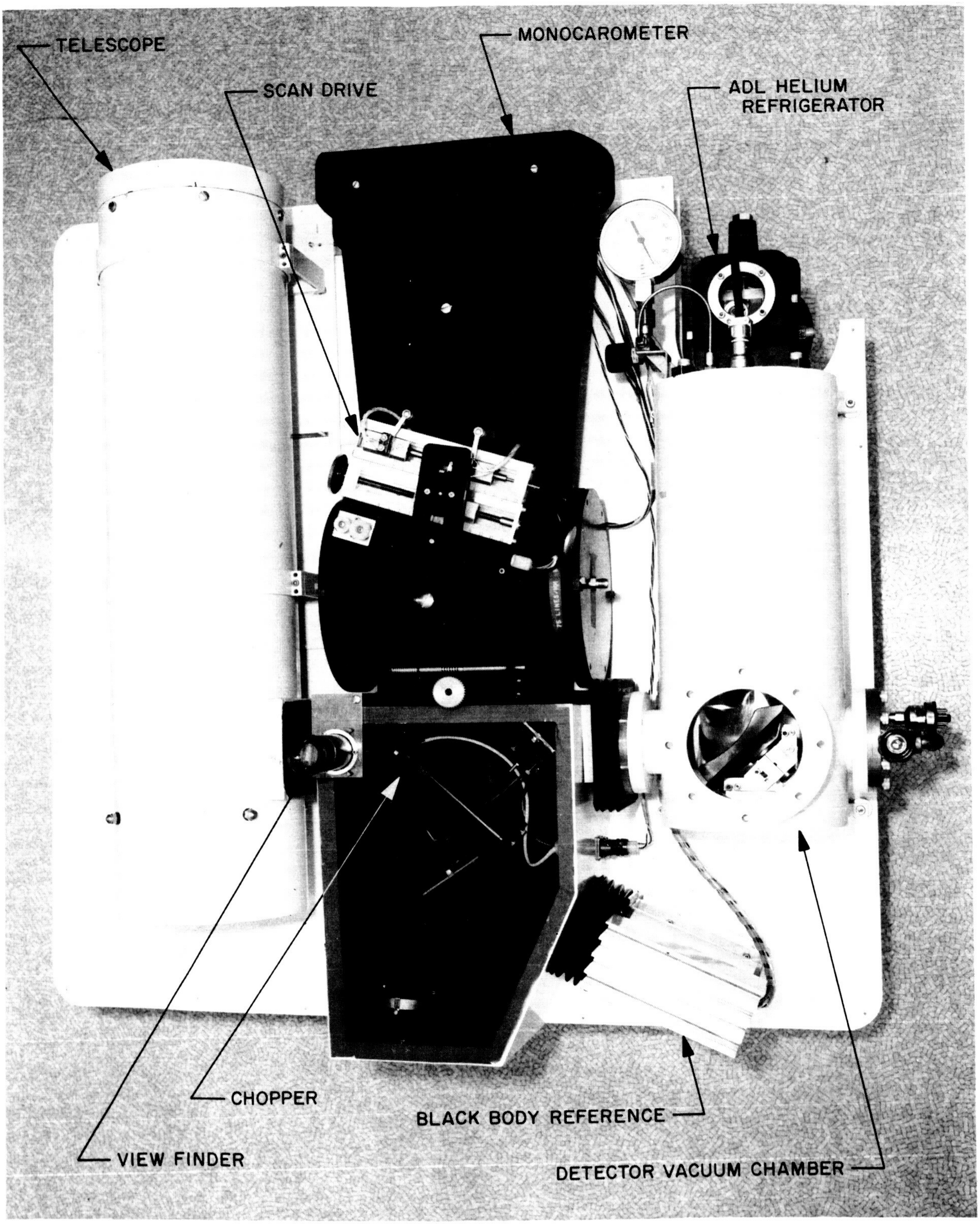


Fig. 1. Portable 8 to 14 μ infrared spectrometer

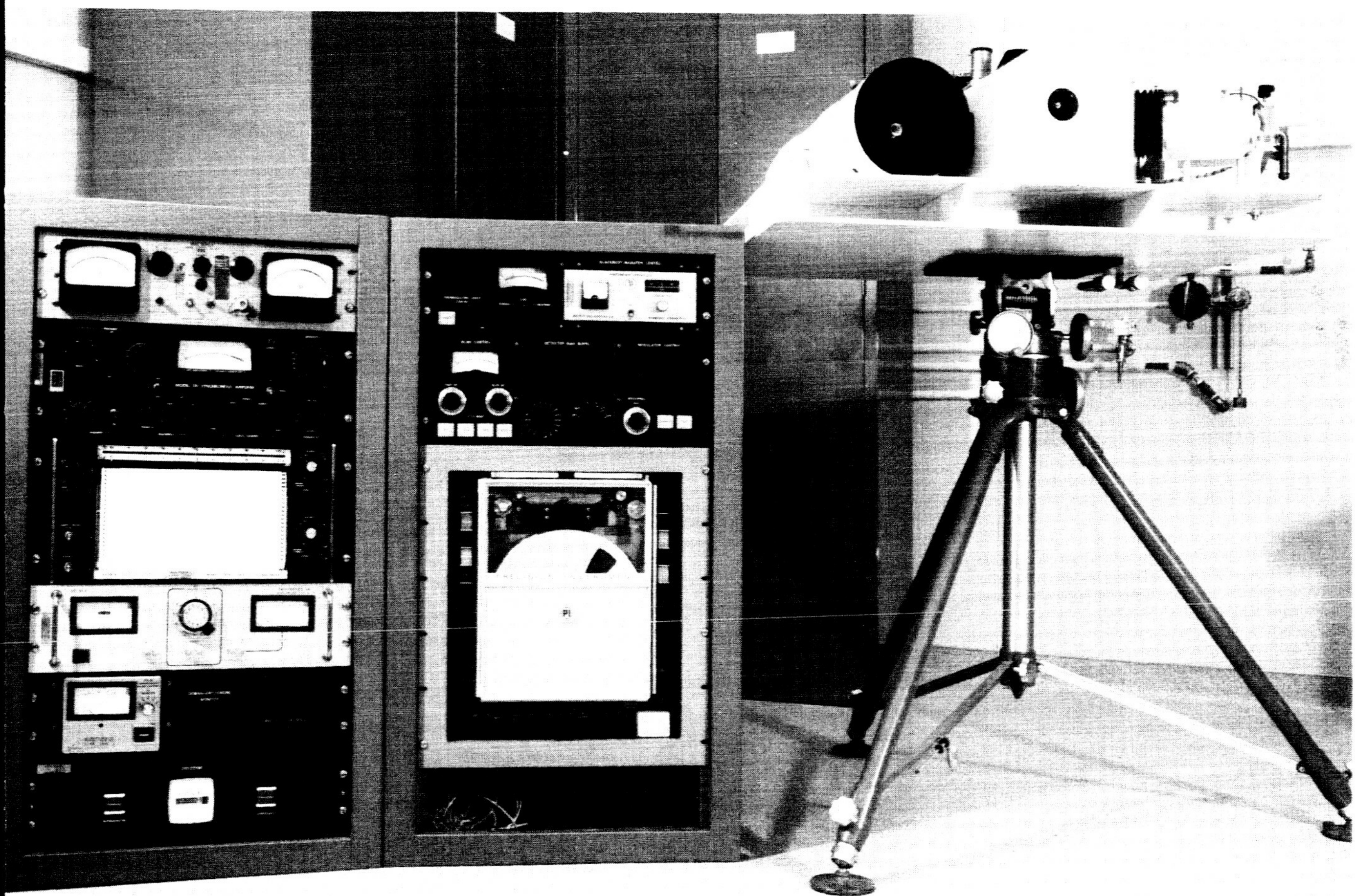


Fig. 2. Infrared spectrometer on tripod with control electronics and tape recorder

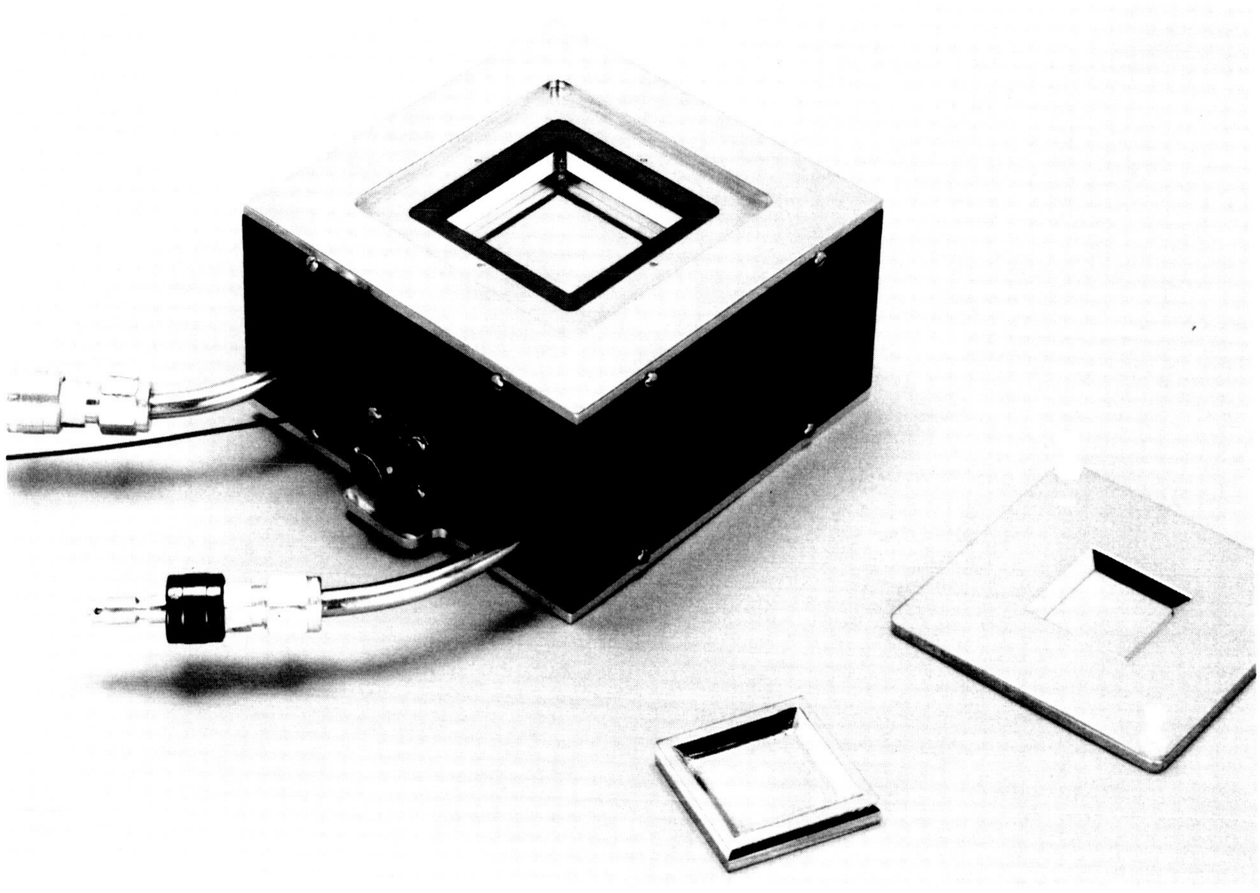


Fig. 3. Sample furnace showing sample tray and removable aperture

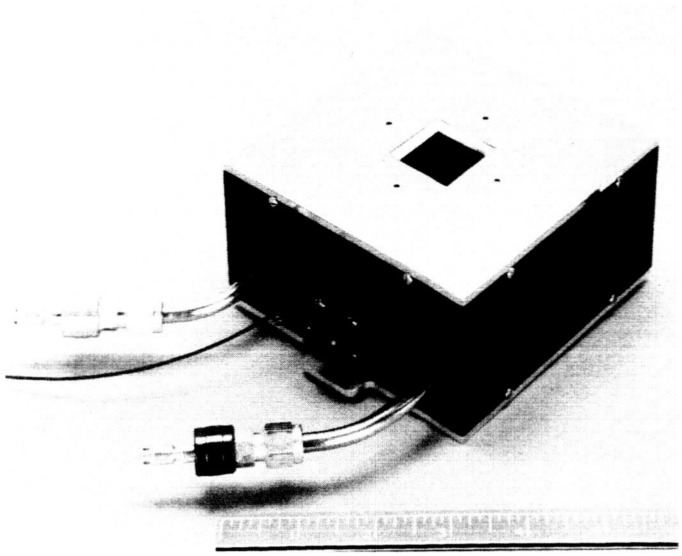


Fig. 4. Blackbody radiator

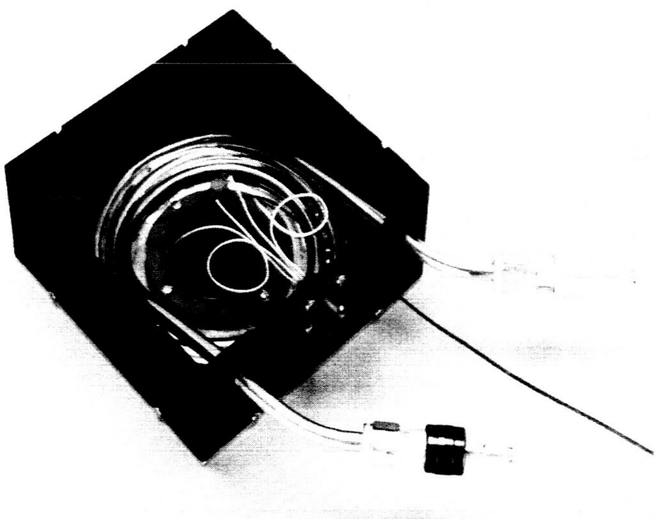


Fig. 5. Internal construction of blackbody radiator

SPECTRAL PHOTOGRAPHY
NASA Work Unit 185-42-20-27-55
JPL 383-20601-2-3250
J. B. Adams

)BJECTIVE

The objectives of the program are (1) to develop a basis for geologic nterpretation of spectral reflectance measurements of planetary surfaces and (2) to evelop a photographic system capable of sensing very faint reflectance differences ınd showing them on a high-resolution image.

'ROGRESS

Laboratory studies of the spectral reflectance of minerals and rocks have been acilitated by the recent procurement of a Beckman DK-2A spectroreflectometer. 'his instrument has allowed extension of the measurements from 0.7 to 2.0μ. Preiminary work indicates that reflectance properties in the near infrared are suffiiently diagnostic to discriminate between grain-size and grain-packing differences n rock samples. Studies of geometric effects on spectral reflectance curves (as escribed in the previous semiannual review) are still in progress.

Interpretation of lunar reflectance data, based on the results of the laboratory tudies, indicates that both compositional and grain-size effects are being observed n the Moon. Compositional differences should be characterized by spectral reflecance (color) differences, without associated large albedo changes. Such differences ave been mapped for the Aristarchus region of the Moon by isodensitracer printouts. 'his information has been made available to the U. S. Geological Survey and has ssisted materially in their stratigraphic and mapping work in this region.

Narrow band-pass photography of the Moon was obtained in May and June using ne Stony Ridge 30-in. reflector under the JPL-Lockheed contract. These observaons complete the contract, and further work will be conducted at the new JPL 24-in. elescope at Table Mountain.

In-house photographic studies are continuing under the direction of E. Dobies, nd in cooperation with R. Newburn and the JPL Astronomy Group. Recent emphasis as been on an error analysis of the lunar spectral photography system. In addition, xperiments have been made on methods of reducing and displaying the multiband nagery which has been taken at the Stony Ridge telescope. Isodensitracer comparion maps (Fig. 1) of different spectral bandpass images (of areas on the Moon) have roved to be especially useful for geologic interpretation. The isodensitracer maps ring out small scale reflectance differences on the lunar images that tend to be averaged" together in photographic composites.

Future work is planned, in cooperation with D. Nash at JPL, to study the ossible effects of proton-induced darkening on the spectral reflectance of rocks. unar spectral photography at the JPL telescope will not be possible for about six ionths. Meanwhile, a cooperative program with the Geological Survey is planned ›r the use of JPL narrow bandpass filters at one of the Flagstaff telescopes. The boratory reflectance studies and lunar photographic observations are being coordiated with lunar spectrophotoelectric work soon to be undertaken by T. McCord at altech.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

Papers Presented at Meetings or Symposia

1. Cronin, J. F., Adams, J. B., Colwell, R. N., and Tifft, W. E., "A Propose Multispectral Photography Experiment for AES Orbital Missions," American Astronautical Society, 1966 (in press).

Publications in the Open Literature

1. Adams, J. B., "Effects of Surface State on the Spectral Reflectance of Rock Powders in the 0.35μ to 2.0μ Range," Journal of Geophysical Research (to be submitted).

JPL Technical Reports

1. Adams, J. B., Dobies, E. F., Filice, A., and Smith, C., Lunar Spectral Photography, JPL Technical Report (in manuscript form; to appear 1966).

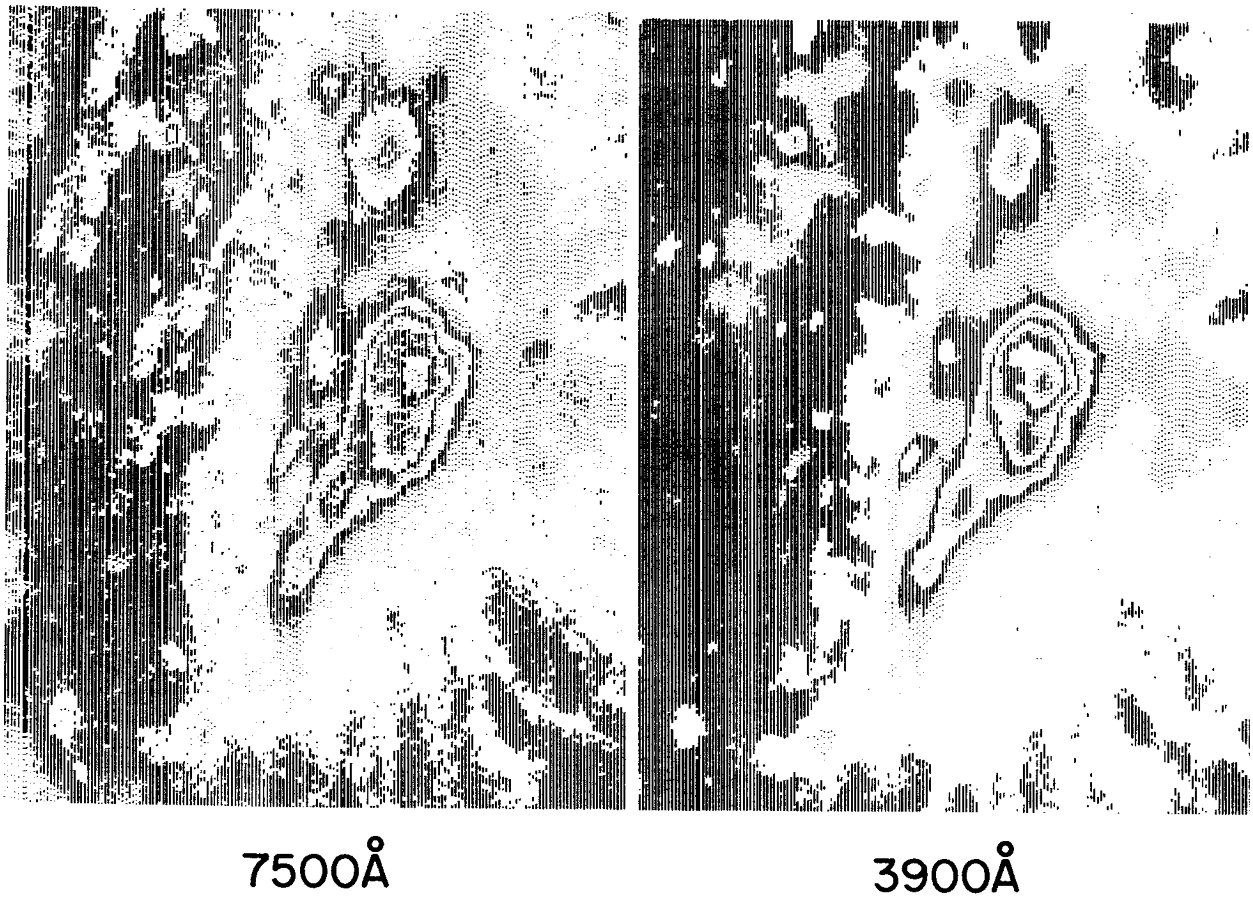


Fig. 1. Isodensity map of the Aristarchus region (0.09 density per step; 10x)

PLANETARY ATMOSPHERES (185-47)
AERONOMY
NASA Work Unit 185-47-01-01-55
JPL 383-70101-1-3280
C. A. Barth

'BJECTIVE

The objective of this task is to conduct a balanced research program in ιboratory, observational, and theoretical upper atmosphere physics.

ERMINAL ACTIVITIES

M. Patapoff spent a major fraction of his time in cleaning up, moving, and ɜcking equipment and supplies for transfer to C. A. Barth at the University of olorado. His other efforts were devoted to moving and setting up the electron para-ıagnetic resonator (EPR) apparatus in a new building, and to measurement of the avelengths of unknown lines in the oxygen afterglow spectra.

This task terminated at the end of FY 1966.

UBLICATIONS DURING FY 1966

PL Technical Reports

Brinkmann, R. T., Green, A. E. S. and Barth, C. A., A Digitalized Solar Ultraviolet Spectrum, JPL TR 32-951, 1966.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

ublications in the Open Literature

Barth, C. A., "Rocket Measurement of Nitric Oxide in the Upper Atmosphere," Planetary and Space Science (accepted for publication in 1966).

MODEL ATMOSPHERES

NASA Work Unit 185-47-26-02-55 (818-01-06-70-80*)
JPL 544-67080-3250
R. A. McClatchey

OBJECTIVE

The objective of this work unit is to establish the physical parameters that define the atmospheres of Mars and Venus, making use of both experimental observations and theoretical calculations.

THE 4.3μ CO_2 BAND TEMPERATURE SOUNDING EQUIPMENT

A procedure for determining a vertical temperature profile from a measured spectral distribution of radiance has been developed. The method is an iterative one in which a very crude first approximation has been shown to converge to a good solution if radiance data in the region of the 4.3μ carbon-dioxide band are available for a few percent accuracy. Figure 1 compares an existing (20-level) temperature profile with the result of application of this iterative procedure when starting with the indicated first approximation. The resulting temperature profile is seen to be accurately determined to within 5°C at any particular pressure level and to better than 2°C when averaged over the atmospheric layers connected by straight line segments.

These are the kinds of results to be expected, when working with real radiance data measured with a spectrometer.

The balloon flight failure of May 1966 will delay the application of this technique to real data until late in this calendar year, when it is anticipated that another balloon flight of a spectrometer operating in this spectral region will be attempted.

ANALYSIS OF ABSORPTION MEASUREMENTS

The possible use of the carbon-dioxide laser as an atmospheric probe has created an interest in the theoretical absorption due to the 9.4 and 10.4μ bands of carbon-dioxides. To obtain agreement with experimental measurements of absorption (Fig. 2), integrated intensities of 0.030 $cm^{-1}/cm\ atm_{stp}$ and 0.018 $cm^{-1}/cm\ atm_{stp}$ were used for the 9.4 and 10.4μ bands, respectively. These integrated intensities were significantly lower than those reported by Burch, et al., of 0.045 and 0.023 $cm^{-1}/cm\ atm_{stp}$, but subsequent measurements by McCubbin, et al., using a carbon-dioxide laser indicate an intensity of 0.015 $cm^{-1}/cm\ atm_{stp}$ for the 10.4-μ band. The present calculations are also in agreement with the theoretical prediction that the state 10^00 has 52% of the strength and the state 02^00 has 48%.

Analysis of Venus spectra obtained by R. Schorn in the 1.05μ region is in progress. Preliminary results indicate a rotational temperature of 190°K for the carbon-dioxide bands observed in the Venus atmosphere.

A similar analysis is being made of the Venus spectra obtained by P. and J. Connes in January of 1966 in both the 1.45 to 1.7μ region and the 1.8 to 2.5μ region.

*Transferred to Voyager Project in FY 1966.

Figure 3 is a laboratory spectrum taken by D. Burch in the 1.6μ region and illustrates the carbon-dioxide bands existing in one of the spectral regions that is being analyzed in the Venus spectra. The spectral resolution of the Connes measur ments is about 1 cm^{-1} and the individual rotational lines in the carbon-dioxide band were resolved. Preliminary analysis of these spectra by L. D. Gray resulted in th identification of new carbon-dioxide bands that had not previously been observed in either laboratory spectra or in the Venus spectra due to the lack of either a sufficiently long path of absorbing gas or to insufficient spectral resolution. The relati abundance of ($^{13}C/^{12}C$) and ($^{18}O/^{16}O$) appears to be the same for Venus as for the Earth. Similar Venus spectra were taken in June 1966, at ten times the resolution. These higher-resolution spectra are being analyzed in greater detail by L. D. Gray

The curves of growth that can be plotted from measurements of the equivalent widths of the carbon-dioxide lines in the Venus spectra lead to ambiguous results when only carbon-dioxide absorption is considered. Therefore, a model of the Ven atmosphere including both absorption and scattering is being developed in order to study the effect of scattering on individual line shape and on the curve of growth. This project is just getting under way, but it is hoped that it will soon lead to new understanding of the Venus atmosphere.

MARTIAN ATMOSPHERIC CIRCULATION

The computer program developed by Yale Mintz of UCLA to solve the general circulation problem in the Earth's atmosphere is being applied to a model of the Martian atmosphere. This is chiefly a monitoring operation, although we will also become more involved in the data reduction in the next fiscal year.

The first Martian atmosphere model that is being run is a 100% carbon-dioxi atmosphere with a surface pressure of 5 mb. It has 2 vertical layers and about 10 horizontal grid points. The integration of the hydrodynamic equations and energy relations is started with the atmosphere in a state of rest with all temperatures (atmosphere and surface) at 200°K. In four days a zonal flow pattern breaks down into a wave regime with Rossby-type waves in the northern hemisphere. Figure 4 an upper level stream-line pattern generated after 14 Martian days from the start the integration. Figure 5 is a corresponding surface pressure pattern. The positi of the Sun is marked with an X on these two figures.

There is now a large amount of data accumulated on this circulation problem and there is much to be done in the coming year to fully understand the implication When these data are reduced, we anticipate that changes will be made in the model and 2 or 3 more such experiments will be run. This should lead to much informati on winds, temperatures and pressures on Mars.

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

1. Gray, L. D., "Calculations of Spectral Absorption for the 9.4-10.4μ Bands CO_2," March 1966 meeting of the Optical Society of America.

2. McClatchey, R. A., "The Use of the 4.3 Micron CO_2 Band to Sound the Temperature of a Planetary Atmosphere," November 1965 meeting of the EN Sensing Symposium at Coral Gables, Fla.

McClatchey, R. A., and Norton, R. H., "Atmospheric Sensing with CO_2 Lasers," November 1965 meeting of the EM Sensing Symposium at Coral Gables, Fla.

Gray, L. D., and McClatchey, R. A., "Atmospheric Absorption from 4.2 to 4.8μ," October 1965 meeting of the Optical Society of America.

Gray, L. D., "Interpretation of Low Resolution Spectra of Mars in the 2μ Region," AIAA 3rd Aerospace Sciences Meeting, January 1966.

ıblications in the Open Literature

Gray, L. D., and McClatchey, R. A., "Calculations of Atmospheric Radiation from 4.2μ to 5μ," Applied Optics, 4, 1624, 1965.

Gray, L. D., "Spectral Absorption of the 4.6μ Bands of N_2O," Applied Optics, 4, 1494, 1965.

Gray, L. D., and Penner, S. S., "Approximate Band Absorption Calculations for Methane," Journal Quantitative Spectroscopy and Radiative Transfer, 5, 611, 1965.

JBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

ıblications in the Open Literature

Gray, L. D., Atmospheric Transmission, Radiative Transfer and Opacity Calculations, S. S. Penner and D. B. Olfe, Eds., Academic Press.

McClatchey, R. A., "The Use of the 4.3 Micron CO_2 Band to Sound the Temperature of a Planetary Atmosphere," Proceedings of the EM Symposium at Coral Gables, Fla., November 1965, Academic Press.

McClatchey, R. A., and Norton, R. H., "Atmospheric Sensing with CO_2 Lasers," November 1965 meeting of the EM Sensing Symposium at Coral Gables, Fla.

Gray, L. D., "Transmission of the Atmosphere of Mars in the Region of 2μ," Icarus 5, July 1966.

Gray, L. D., "Transmission Calculations for Carbon Dioxide I: the 9.4μ and 10.4μ Bands," Journal Quantitative Spectroscopy and Radiative Transfer.

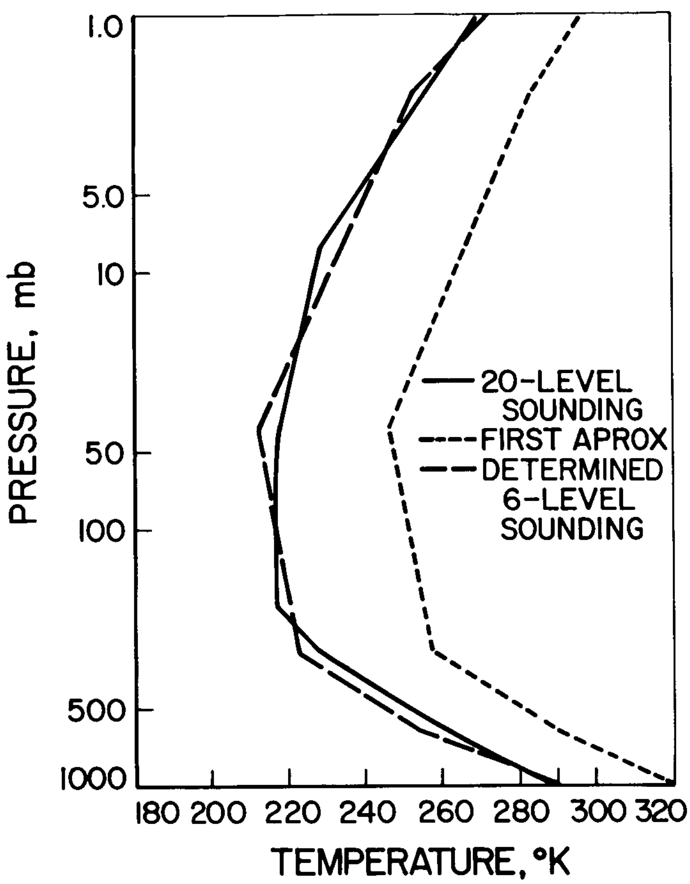


Fig. 1. Comparison of calculated and "correct" 20-level temperature profiles

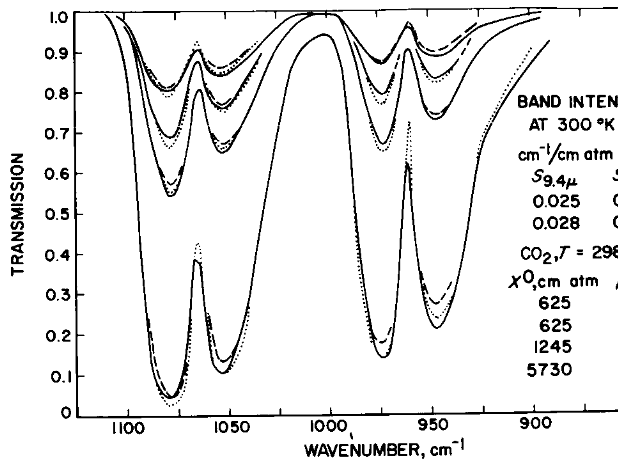


Fig. 2. Comparison of calculated an experimental transmission i the 10-Micron bands of CO_2

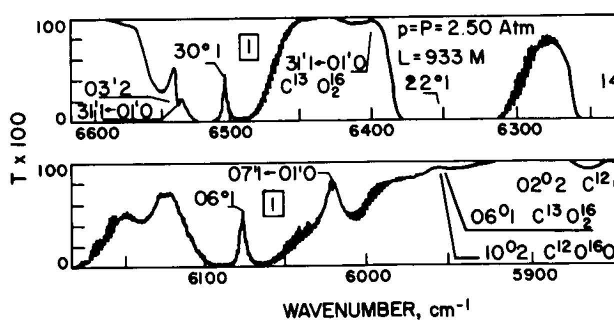


Fig. 3. Spectrum of the 5800-6600 cm^{-1} region

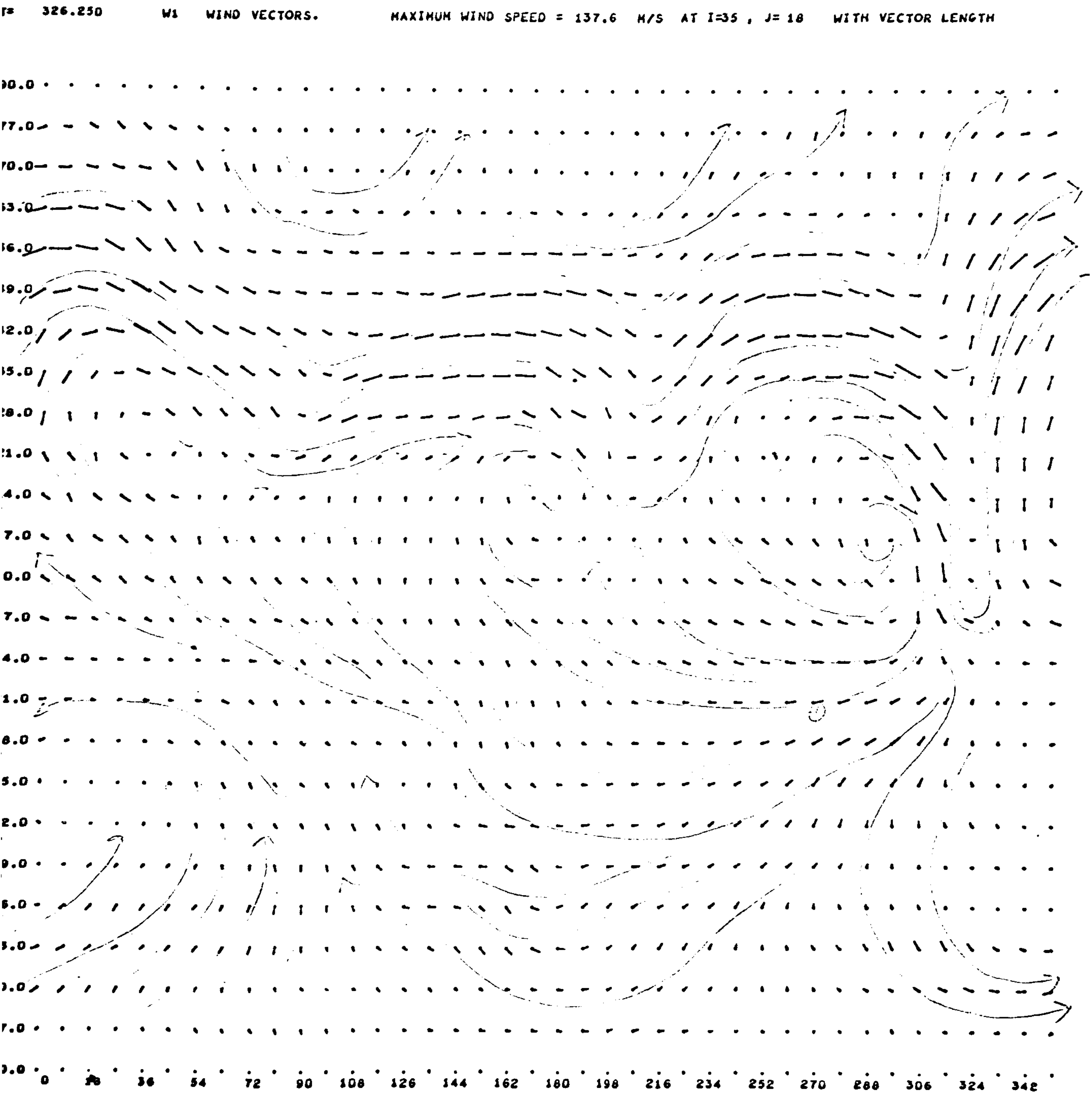


Fig. 4. Upper-level stream-line pattern

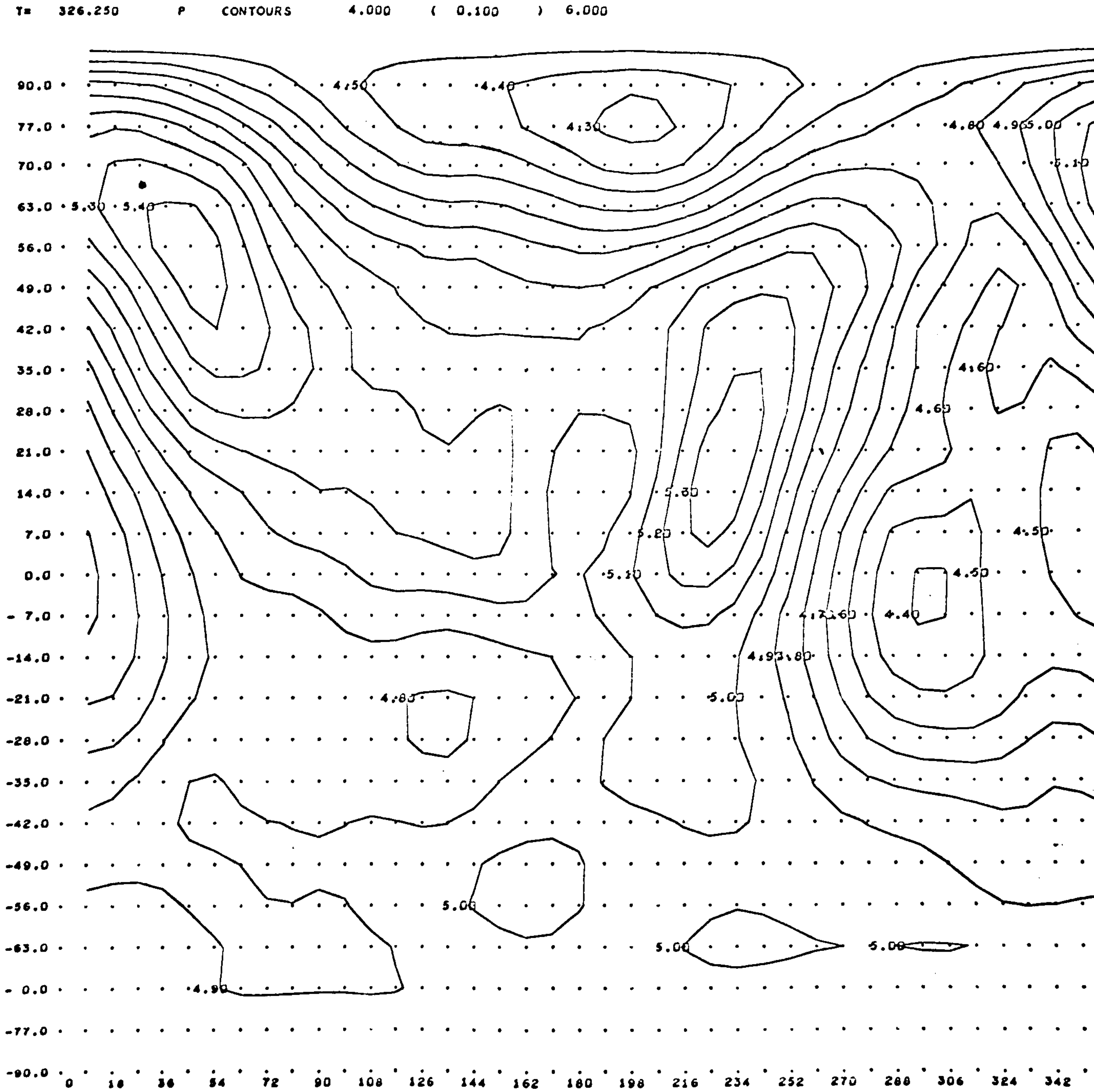


Fig. 5. Surface pressure pattern

ADVANCED TECHNICAL DEVELOPMENT (186)

PLANETARY QUARANTINE STERILIZATION (186-58)
ACTUATOR STERILIZATION

NASA Work Unit 186-58-02-01-55
JPL 384-82801-2-3440
Gerald S. Perkins

OBJECTIVE

The objective of this task is to provide sterilizable spacecraft control actuators and components for future space exploration programs.

JET VANE ACTUATOR

An advanced type jet vane actuator being developed to satisfy typical autopilot performance requirements is under development at Aeroflex Laboratories, Inc., in Plainview, Long Island, New York. This actuator, when completed, will have eliminated ball bearings and a feedback potentiometer. Instead, it will use flexural type bearings and a moving coil torquer. The actuator will have a linear curve of position vs coil current as servo feedback information.

The development of the flexural bearing is the immediate problem. A tri-flex cross beam type structure appears to be the preferred configuration. It has been possible to experimentally verify the analytical definition of the flexural bearing. A large scale-model was built for this experiment. The first bearing model used beams of constant section properties. This verified the analysis but its geometric requirements made it impractical for reduction to a size compatible for use in the experimental jet vane actuator. From these results, it was then concluded that a tapered width configuration for the cross flex beam would be geometrically compatible with the size required in the actuator. An analytical definition has been prepared taking into account the tapered beam configuration. It treats each beam as a cantilever with a load and opposing moment at its end. Parts are being fabricated for the model analogy experiment.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

HIGH-TEMPERATURE PHOTOCATHODE IMAGE DISSECTOR
NASA Work Unit 186-58-02-02-55
JPL 384-82501-2-3440
D. S. Herman

OBJECTIVE

The objective of this work unit is to develop a sterilizable photocathode image dissector. The specific photocathode being developed is a bi-alkali type not containing cesium.

INTRODUCTION

Since the Mariner IV Canopus Sensor has shown that the electrostatic image dissector (ID) is a superior detector where high sensitivity, long life, and ruggedness are important, it has many potential applications. For example, in the exploration of Mars it could be used as a star sensor, approach guidance sensor, landing guidance sensor or low-bit-rate, low-power long-life T. V. Some of these potential applications would require the sensor to be capable of withstanding ethylene oxide decontamination and heat sterilization. A bi-alkali photocathode not containing cesium was used for this reason in both photomultiplier tubes and ID tubes. The photomultipliers were used to obtain the proper technique for producing the bi-alkali photocathode which was then used in the ID tube.

STERILIZABLE ELECTROSTATIC IMAGE DISSECTOR (SEID) CONTRACT

The contract and a final report were completed during the past quarter. Prior to the sterilization treatment good tubes were obtained. These tubes had good photo response and their characteristics met almost all of the required specifications.

The tubes appeared to be capable of withstanding ethylene-oxide decontamination without any adverse effects. However, heat sterilization affected the properties to the extent that the tubes could not meet the Voyager type approval sterilization requirements due to changes in its characteristics. In addition, some of the properties changed irreversibly. However, one of the tubes met almost all of the requirements. This one tube's photocathode was prepared differently from the others because of an accident during processing. It is hoped that this tube's processing history may be the clue to the proper technique for preparing high temperature photocathodes for ID tubes.

FUTURE ACTIVITIES

The work in the area of high temperature photocathode is being followed up on a new contract which will combine this work with the work on the electro optical experiments of the ID tube (NASA Work Unit 186-68-02-05-55). Bi-alkali photomultiplier tubes will again be used to develop the proper technique. The processing procedure which gave the good tube above will be the starting point. Once the proper or best technique has been obtained, ID tubes will be fabricated for testing. Two tubes will be tested at the Voyager Type Approval level and two tubes at Flight Acceptance level. After testing, these tubes will be put through life testing at specified test conditions.

PUBLICATIONS DURING FY 1966

Contractor Reports

1. Karpinski, J. Z., "Final Report, The Development of Sterilizable Image Dissector Tubes," CBS Laboratories, May 15, 1966, JPL Contract No. 95078

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

INERTIAL SENSORS - STERILIZATION
NASA Work Unit 186-58-02-03-55
JPL 384-82701-2-3440
P. J. Hand

)BJECTIVE

The objective of this work unit is to develop inertial sensors capable of meeting hermal sterilization requirements. The specific objective in the area of gyros is to evelop the Honeywell Type DGG159D1 miniature gas bearing floated gyroscope into a evice capable of surviving six thermal sterilization cycles without either catatrophic failure of significant degradation of performance. In the area of acceleromter development, the goal is to develop a high accuracy guidance type accelerometer apable of withstanding six thermal sterilization cycles without either catastrophic ailure or significant performance degradation.

;YRO DEVELOPMENT

The performance of the first gyro delivered to JPL as part of this effort was eported on in JPL TM 33-272. At that time six cycles of the new sterilization rocedure had been performed but no drift data were available. This data has since een obtained and is shown in Table 1. Following the six-cycle sterilization, three nore cycles were performed. This resulted in a complete failure of the spin motor. ls was reported earlier, the motor in this gyro has a history of anomalous behaviour uring start up. This condition continued to degrade with each sterilization cycle esulting in complete failure to synchronize after the ninth cycle.

Delivery of the second gyro was made early in 1966. This instrument was iven initial testing at JPL and was immediately rejected to the manufacturer due to n out-of-specification condition on mass unbalance. The gyro was reworked and eturned to JPL for further testing. At this time, it was noted that the suspension luid pump was shorted to the case. As this was not a catastrophic failure, it was lected to proceed with thermal sterilization. The first cycle resulted in a shift of .6 deg/hr in the mass unbalance. This shift was also beyond specification limits nd the gyro was again rejected to the vendor for repair.

Future work will be to resume evaluation of this gyro as soon as it is returned rom Honeywell, Inc.

.CCELEROMETER DEVELOPMENT

The performance of the first two standard instruments purchased was escribed in JPL TM 33-272. The rebuilt unit reported on at that time was subseuently subjected to vibration as part of a detailed environmental study. The nstrument's internal suspension system failed at a level of 10-g rms random noise. 'his was a catastrophic failure and the unit was returned to the vendor for repair.

The manufacturer of these instruments (Bell Aerosystems Co.) has analyzed ie two vibration failures and has instituted several design modifications to these nstruments to increase their vibration capabilities. The vendor has performed ibration tests at the vendor's facility, which indicate the redesigned units should be

able to survive the JPL environment. These two units are due back at JPL during the middle of 1966.

An RFP was sent in January 1966 to Bell Aerosystems to propose on a progra to develop this accelerometer into a sterilizable instrument. The proposal has bee returned, analyzed, and approved. The program is now in the contract negotiation phase and is expected to be approved in approximately one month.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

Table 1. Performance of DGG159D1 gyro

Presterilization	Reaction torque	Mass unbalance, spin axis	Mass unbalance, input axis
Cycle 7	-1.08°/hr	+1.36°/hr	-1.27°/hr
Post cycle 7	-1.19	+0.833	-1.27
Post cycle 8	-1.09	+0.544	0.869
Post cycle 9	Motor failed to synchronize		

STERILIZABLE PHOTOCONDUCTIVE DETECTORS
NASA Work Unit 186-58-02-04-55
JPL 384-81401-2-3440
D. G. Carpenter

BJECTIVE

The objective of the work unit is to develop qualified sterilizable photoconduc-rs, either by test and evaluation of presently available devices, or fabrication and ıalification of special photoconductors built to JPL derived specifications. A suit-ɔle photoconductor will be sterilizable, will have high sensitivity, long-term ability, and high reliability. The sterilization requirements are six cycles 6 hr/cycle) at 135°C.

RESENT ACTIVITIES

During the present report period no work was accomplished under this work ıit.

The present status of knowledge shows that presently available sintered ıdmium sulfide photoconductors are not sterilizable. A contract with Autonetics, nded from a FY 1965 work unit (186-68-02-16-55), has produced vacuum deposited ıotoconductors that are sterilizable to present temperature levels. However, these ıits have other operational deficiencies that need improvement.

UTURE ACTIVITIES

Due to funding limitations and priority of other tasks, this work unit is being ıspended until FY 1968.

During the interim, work is progressing under another work unit (OART: 129-2-05-01-55) on the vacuum evaporation of cadmium sulfide materials. It is believed at valuable information will be obtained, enabling JPL to continue this program in Y 1968 with improved guidelines.

JBLICATIONS DURING FY 1966

None.

JBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

STERILIZATION OF CAPSULE CONTROL SYSTEMS
NASA Work Unit 186-58-02-05-55
JPL 384-80301-2-3440

R. Mankovitz

BJECTIVES

The objectives of a systems effort in sterilization investigations are: (1) to fine the components required for guidance-and-control subsystems on landing cap-les, (2) to establish new subsystem designs when current mechanizations cannot be erilized, (3) to study the compatibility of component sterilization methods with stems-level sterilization techniques, and (4) to establish testing philosophies and ocedures for final systems tests. Since the component investigations are dependent on objective (1), this task must be undertaken first. The remaining objectives have rong interrelations with the component programs and are being studied multaneously.

TRODUCTION

Capsule control system components can be broadly placed into five categories:) actuators, e.g., stepping motors and valves; (2) celestial sensors, e.g., photo-thode image dissectors; (3) inertial sensors, e.g., gyros and accelerometers;) Sun sensors, e.g., photoconductive detectors; and (5) control electronics, e.g., rvoamplifiers and switching logic. In addition to assessing the effects of steriliza-on on these five categories, one must also evaluate the compatibility of the system nctional test requirements with system sterilization techniques. In the area of quired components, during the reporting period, the capsule control system com-nent sterilization effort was monitored to assure that all attitude control compo-nts which would be required for a capsule system are undergoing sterilization vestigations to ensure compatibility with system requirements. This effort will ntinue in FY 1967.

The discussion below indicates the problems anticipated in the sterilization of ntrol electronics, and the steps being taken to ensure meeting the time-mperature cycle goal of 145°C for 36 hr in three cycles.

ONTROL SYSTEM ELECTRONICS

An electronic component sterilization test program has been initiated to deter-ine the parts capable of withstanding several 36-hr periods of nonoperational orage at 145°C without significant degradation. Preliminary results indicate that a ajor problem area may be large-value electrolytic capacitors. Presently, solid d foil tantalum units, with ratings up to 47 μf, 35 v have been tested successfully.

Capacitors used in the attitude control system for timing applications (e.g., the ll search inhibit circuit uses 270-μf, 15-v units), derived rate feedback (540 μf, v), and gyro loop feedback (four 1020-μf, 20-v units/loop) require the use of wet-ıg and foil-type capacitors. It is believed unlikely that these types will survive; wever, no tests have been conducted on these units. Anticipating failure of the its, alternate circuit mechanizations that do not require these units were vestigated.

Timing Circuits.

Figure 1 shows the mechanization for a timing circuit yielding time intervals to 100 sec using a 2-μf capacitor. The circuit is basically a digital counter operati from a 1 pps source. The pulse source could be a unijunction oscillator, or it may originate from the CC&S clock. The counting is accomplished by two (divide-by-te microelectronic counters, serially coupled through a NAND gate. Any number of counters can be connected serially, with the output of the n^{th} counter yielding a pul every 10^n sec. Outputs can be obtained at any count by merely connecting NAND gates to the proper Z outputs (see table of output states in Fig. 1). To assign a figure of merit to the circuit for its ability to decrease the size of the timing capac tor, it is apparent that the counter decreases the R-C time constant equivalent by t counter scale (e.g., 100 in this case). The size of each (divide-by-ten) counter is the same as a single T0-5 transistor case, and they have a non-operating temperature range to 150°C. It is interesting to note that a single-pulse generator (and he capacitor) can be used to operate many counter circuits, each controlled by a separate gate. With the pulse generator free-running, the maximum error in the count 1 sec. Due to the high reliability of silicon semiconductors, the reliability of this type of timing circuit may be considerably greater than the conventional R-C circu

Derived-Rate Circuit

Figure 2 shows the mechanization for a derived rate circuit yielding charge-discharge time constants of about 100 sec. To decrease the capacitance necessary for D/R feedback, an active integrator, using a micro-electronic operational ampl fier, is used. Circuit operation is as follows: assume the switching amplifier (+) output is energized due to a position error signal. A voltage (e_1) appears as an in to the integrator. As the integrator output begins to ramp, the high-gain feedback amplifier saturates, generating ($-e_{disc}$) as a second integrator input. The voltage (V_{charge}) which is summed with the position error signal, is hence

$$V_{charge} = \frac{-\left(e_1 - e_{disc}\right)t}{R_{S4}C},$$

When the switching amplifier goes off, (e_1) is zero and the voltage

$$V_{disc} = V_{charge} \mp \frac{\left(e_{disc}\right)t}{R_{S4}C}$$

It appears that the discharge time constant is the determining factor in choos ing D/R feedback networks; hence to assign a figure of merit to this circuit, Eq. (must be compared with that of an ordinary R-C circuit. For an R-C circuit:

$$V_{disc} = V_{charge}\left(e^{-t/RC}\right)$$

ɜxpanding $e^{-t/RC}$ for T < RC yields

$$V_{disc} = V_{charge} - \left(\frac{tV_{charge}}{RC}\right) \tag{4}$$

Comparing Eq. (2) and (4), it is apparent that (V_{charge}/e_{disc}) represents the capaci-
or reduction factor. If (e_{disc}) is equal to 0.05 V_{charge}, for example, the D/R
capacitor can be reduced by twenty, yielding 27 μf instead of 540 μf for the R-C case.
Although 27 μf is not a small value, it does allow for use of non wet-slug type capaci-
ors for this application.

The zener diodes in series with the switching amplifier outputs prevent transis-
or switch leakage from appearing as an input to the integrator in the "off" condition.

The high-gain feedback loop around the integrator prevents drift (which could be
considerable over long time periods) due to noise or offset voltages. The circuit is
essentially locked to zero. The small size and high reliability of microelectronic
analog circuits makes them ideal for this application. The units have been stored at
emperatures to 150°C.

Gyro Rate + Position Circuit

Figure 3 shows the mechanization for a rate-plus-position gyro circuit which
can be used to eliminate large feedback capacitors. The approach used in the past
was that of feeding back a current to the torquer through a series capacitor. This
closed-loop system requires large capacitance values (4080 μf), which, in addition to
he sterilization problem, requires large volumes, and degrades the accuracy of the
system (due to leakage currents).

The circuit shown in Fig. 3 uses a wide-angle gyro in an open-loop position
eedback configuration, with the output passed through a lead-lag network. To assign
figure of merit to this circuit for decreasing the value of capacitance, let us
xamine a typical active lead-lag network (Fig. 3). Investigation of previous systems
ndicates that a lead time constant (τ_1) of 10 sec is typical. Assuming (R_1) and (R_2)
re 500 K resistors, and a lead-lag ratio of 10 is desired, the values for (C_1) and
(C_2) are 20 μf and 2 μf, respectively. Comparing this with the 4080 μf for closed-
oop systems, it is evident that a reduction factor of 200 is possible with this
nechanization.

Parts for constructing these, and several other circuits designed to replace
ossible "weak spots" (such as interstage transformers) have been procured during
he reporting period. Approximately 90% of the components have been received, and
readboarding, functional and sterilization testing has begun. When the testing is
ompleted, the circuit performance will be compared with the sterilizable component
eliability data compiled to that time by the component parts group, and recommen-
ations will be made in the area of electronic subsystem redesign.

In addition, during the next report period, the sterilization considerations of
unctional testing (e.g., high temperature-short time vs low temperature-long time
eat cycles) will be investigated.

PUBLICATIONS DURING FY 1966

1. Nicklas, J. C., Bachman, W. E., Davis, E. S., Koch, E. F., and Mankovit R. J., "Guidance and Control System Sterilization," presented at First Annu National Conference on Spacecraft Sterilization Technology, November 17, 1965.

2. SPS Contribution

   Mankovitz, R., "Sterilization of Capsule Control Systems," SPS 37-37, Vol I pp. 43-47.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

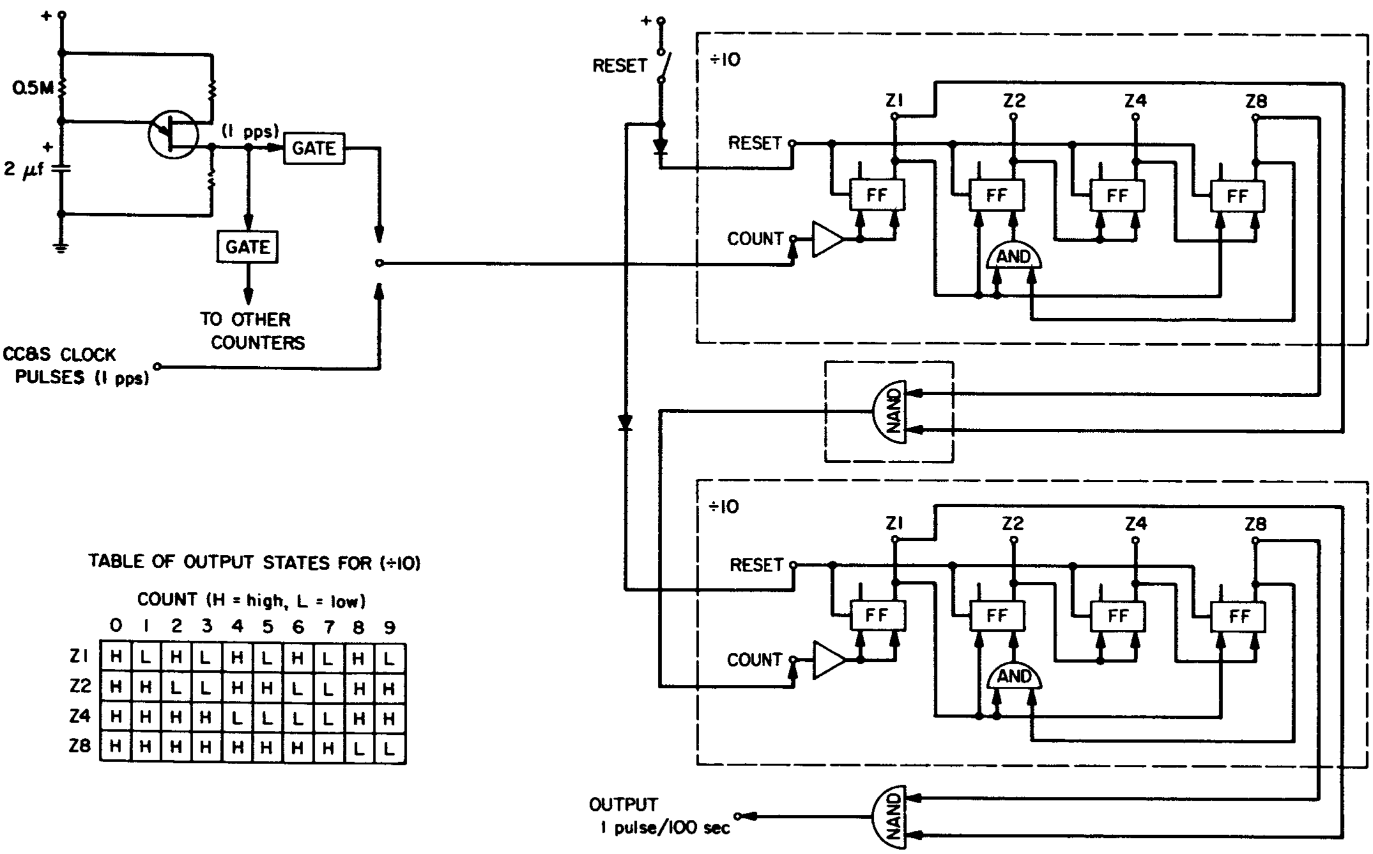


TABLE OF OUTPUT STATES FOR (÷10)

COUNT (H = high, L = low)

	0	1	2	3	4	5	6	7	8	9
Z1	H	L	H	L	H	L	H	L	H	L
Z2	H	H	L	L	H	H	L	L	H	H
Z4	H	H	H	H	L	L	L	L	H	H
Z8	H	H	H	H	H	H	H	H	L	L

Fig. 1. Timing circuit mechanization

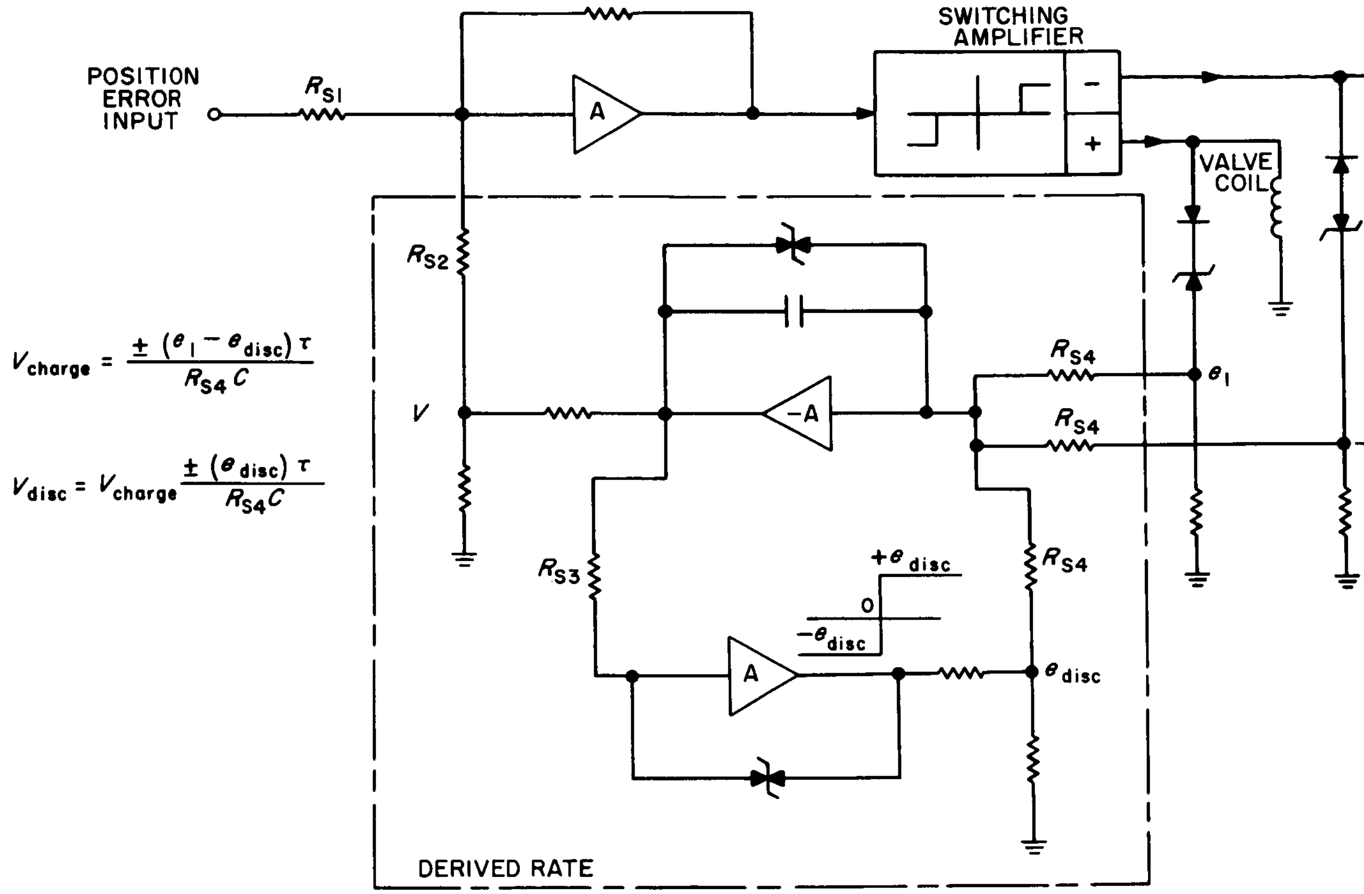


Fig. 2. Derived rate mechanization

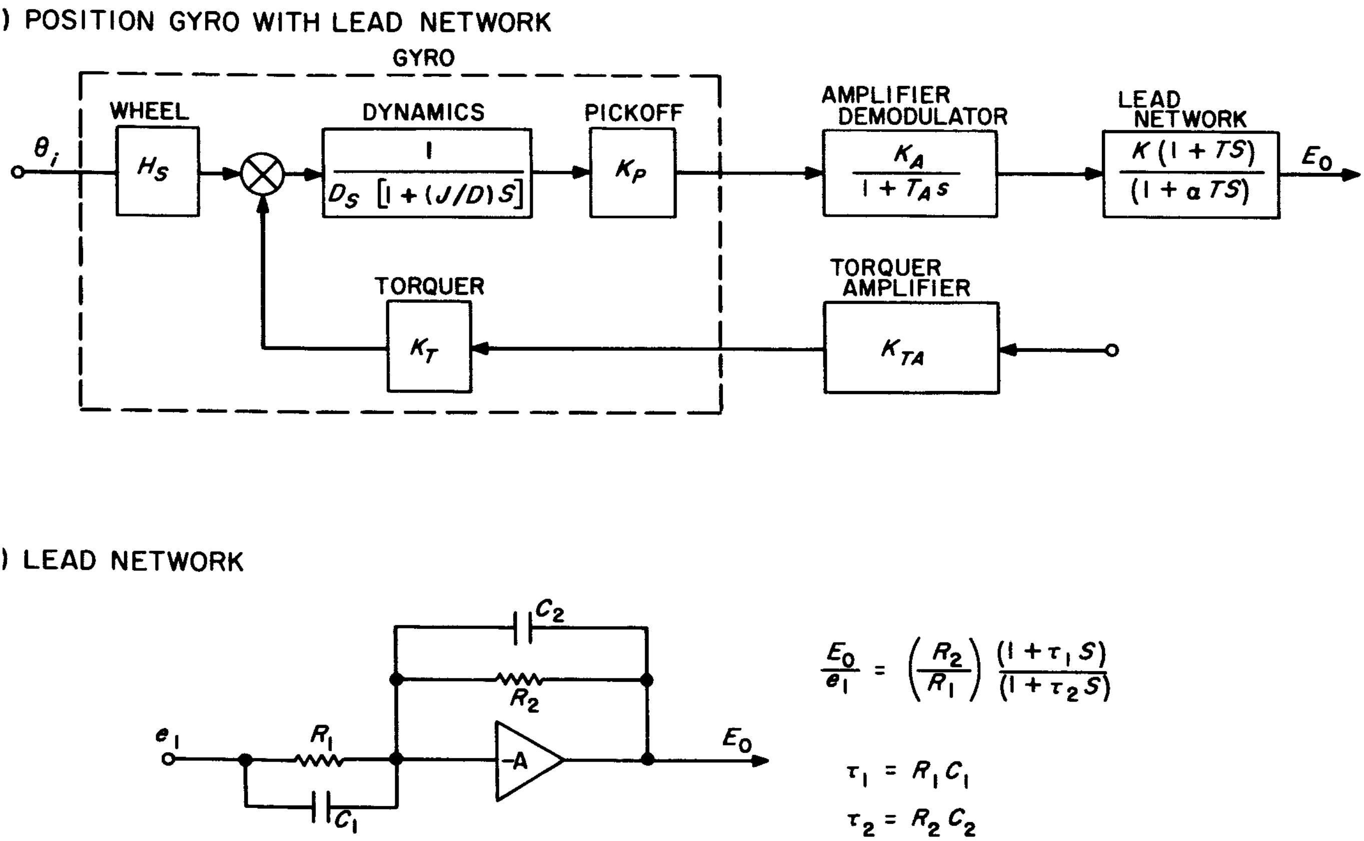


Fig. 3. Gyro rate plus position circuit

SPACECRAFT DIGITAL MAGNETIC TAPE RECORDER STERILIZATION

NASA Work Unit 186-58-03-01-55
JPL 384-85601-2-3340

J. K. Hoffman

)BJECTIVE

The objective of this work unit is to define and solve the problems associated ith the heat sterilization and chemical decontamination of a typical spacecraft agnetic tape recorder.

IATERIAL STERILIZATION STUDIES

)bjective

This task was initiated to study the effects of sterilization environment on aterials used in the construction of magnetic tape transports. The study is to nclude both thermally induced changes in individual materials and the mutual reacions among these materials in a sealed case.

ieneral Background

A Mariner IV type of magnetic tape transport was subjected to a dry-heat sterlization program. Subsequently, the unit failed to operate satisfactorily, necessiating an investigation into the cause and nature of the failure.

During the previous reporting period (July 1 to December 31, 1965), a program f analysis and evaluation of each of twenty-eight component materials used in the ape transport was undertaken. The investigation was initiated to determine the bility of the selected materials to withstand the dry-heat sterilization cycle (three 6-hr periods at 145°C in an 18-psi dry-nitrogen atmosphere), and to obtain inforation relative to their mutual compatibility under those conditions.

The unit was disassembled in a clean-room environment. All critical rotating omponents were examined for significant dimensional changes. None were apparent. nalysis of the failed capstan bearings revealed lubricant breakdown and dissipation s the primary cause of failure. There was no evidence of contamination of the ıbricant by solids from sources outside the bearing. However, gaseous or liquid ontamination remains to be verified. It was established that the magnetic tape inder decomposes at elevated test temperatures releasing HCl which probably ccounts for the severe corrosion observed on some of the metallic components.

.ctivities During Report Period

An investigation of the motor bearings has revealed that the lubricant is in the ery early stages of deterioration leading to ultimate bearing failure. Indications re that the same process of lubricant breakdown and dissipation that contributed to ilure of other bearings in the system was taking place, but at a slower rate. The pparent longer life of the motor bearings is considered the result of better lubricaon due to their higher operating speeds, and greater isolation and, therefore, ffective shielding.

Component materials analysis at JPL has continued with some delays due to relocation of facilities and priority problems. However, all weight loss measurements and corrosion tests have been completed. Approximately 90% of the assigned physical and mechanical property tests have also been carried out. The volatile condensable material and appropriate infrared spectrum determinations have been performed on about 20% of the products.

Weight loss has been most severe among the adhesive group with as high as 28% for one material. Generally about 20% of the materials show more than 3% loss The significance of the weight loss characteristics remains to be evaluated relative chemical interreactions and the relationships to physical properties of the various materials. Corrosion tests, although not fully evaluated yet, indicate that a fewer number of the materials have adverse effects on the metals tested than initially suspected. Metals included in the tests were: brass, copper, Mu metal, steel, and magnesium. Results of the program so far indicate the necessity for very careful selection of items such as bearing lubricants, tape binders, and adhesives and othe non-metallics for spacecraft tape recorder applications.

Future Activities Planned

Work will continue on the investigation and evaluation of materials used in the tape recorder. A final report will be prepared which will cover in detail all observ tions and findings relative to the investigation, including conclusions and recommen dations. Completion is expected early in FY 1967.

KAPTON DRIVE BELT STUDY

Objective

The objective of this task is to evaluate Kapton as a tape transport drive belt material, and to establish design and reliability criteria relative to the following parameters:

1. Fatigue life.
2. Stress relaxation and storage characteristics.
3. Coefficient of friction.
4. Duty cycle effect.
5. Environmental capability.

General Background

Seamless Mylar (polyester) belts have been the mainstay for torque transmis sion in spacecraft tape recorders for the past several years. Mylar films, howeve are susceptible to permanent damage at temperatures in the vicinity of 75°C (Mariner TA limit is 75°C). Also, the fatigue life of Mylar belts is a serious prob lem in the design of long life tape recorders. Kapton film belts are reported to wi stand temperatures of 400°C without damage, and are also reported to possess superior fatigue life properties at conventional spacecraft temperatures. A work statement was prepared for a year-long study program. A proposal has been submitted and negotiations leading to contract award were opened.

.ctivities During Report Period

Contract negotiations continued.

uture Activities Planned

Award of a contract will be expedited. Work will commence.

'UBLICATIONS DURING FY 1966

'apers Presented at Meetings and Symposia

. Arens, W. E., "Sterilizable Communication and Data Handling Systems," NASA, National Conference on Spacecraft Sterilization Technology, November 16-18, 1965, Jet Propulsion Laboratory.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

MINIATURE ELECTRO-OPTICAL IMAGE DETECTOR STERILIZATION

NASA Work Unit 186-58-06-03-55

JPL 384-84301-2-3230

L. R. Baker

ECTIVE

The present technology related to vidicons for space imaging system application not made available vidicons capable of meeting present sterilization require-ts. Additionally, it is logical to assume that any sterilizable component would application in a high-impact environment. Therefore, the purpose of the pro-n is to design, fabricate and test a vidicon-type image sensor capable of surviv-three cycles of dry heat sterilization at 145°C for a period of 36 hr each, and also ible of surviving ETO decontamination. The tube elements and structure are g designed to withstand a 3000-g shock, since a sterilizable component will cally find application in a high-impact environment. (The ruggedization aspects being funded by a companion OART Work Unit 125-24-01-05-55.)

The program was logically divided into two phases to run concurrently. Task I the development of the sterilizable photoconductor, and task II was the develop-t of the complete ceramic vidicon incorporating the sterilizable photoconductor.

GRESS

k I

The task I effort was successfully completed on schedule in March, and the I final report was written and submitted. During task I, a total of 51 type 7735a s envelope vidicons were made incorporating the sterilizable photoconductor. tubes were operated in a test set to determine the operating characteristics and passed through the entire sterilization compatibility test accordin g to JPL ifications XS0-30275-TST-A and GMO-50198-ETS. Of the 51 tubes, 45 were pletely and satisfactorily sterilized. The remaining 6 tubes were accidental res. The main problem with the temperature of sterilization has been an ease in dark current by, generally, a factor of two. However, a slight increase e oxygen content of the photoconductor during application has decreased the dark ent initially so that the increase in dark current is not considered a problem. re 1 shows the distribution of the 45 tubes in terms of the increase in dark cur-before and after 3 heat sterilization cycles. It is seen that at a target voltage of , the most probable value of dark current increase due to sterilization was ±0.15, while the mean value was 1.65. Approximately 50% of the tubes had a of or below 1.65; 60% had a ratio of or below 2.0; 85% a ratio of 2.5 or less. above results are complicated by the temperature dependence of the dark cur-variation of which can be comparable to the changes caused by the sterilization s.

In general, the sensitivity of the photoconductor increased as a result of steri-ion, but by a smaller percentage than the dark current. Figure 2 shows the ibution of 44 vidicons as to change in signal current at 20 v target voltage and rm illumination of 1 lumen/ft^2. The most probable ratio of sensitivity after lization to initial sensitivity, as well as the mean value of this ratio, is about .

The light transfer characteristics before and after sterilization indicate tha
the photoconductor is not sensitive to sterilization as far as shape and slope of th
curve are concerned. The gamma of the photoconductor generally falls in the ra
of 0.68 ±0.04.

Of the remaining photoconductor operational and image parameters to chan
significantly due to sterilization is the resolution. The distribution of 44 tubes,
before and after sterilization is shown in Fig. 3. The average resolution was fo
to have decreased from an average of 500 television lines to 460 TV lines. Of th
tubes tested, 27 decreased, 5 remained unchanged, and 12 increased resolution
ing sterilization.

Based on the above results, the photoconductor developed during task I is f
sterilizable.

Task II

The first complete ceramic vidicon, as shown in Fig. 4, was fabricated in
January, but air leaks in some of the brazed joints eventually ruined the tube. H
ever, it did operate for a short period and demonstrated 100 TV line resolution.
fabrication jigs and the brazing operations were redesigned to improve the braze
joints. After the tube failed it was designated a mechanical sample and was subj
to 3100-g shock. Because of problems with the shock mounting fixture, the tube
damaged during shock testing. The fixtures were redesigned, and subsequent te
has shown no further fixture problem.

Early tests on the heater-cathode subassembly at 3100 g indicated a good
degree of survival. However, the cathodes in these tests were unactivated catho
It was felt that further testing should be done on subassemblies with activated
cathodes, and these tests did indeed show a much higher failure rate. X-rays of
tested units showed the filament coil was not seated sufficiently within the cathoc
to properly restrain it during shock. A new process has been developed which
restrains the filament by brazing the top of the coil to the cathode cup. Tests a
now being conducted on sample subassemblies.

One of the complete and operational ceramic vidicons made recently was
brought to JPL to shock test on the 50-ft drop tower. Mechanical samples were
dropped first to test the adhesion of the viscoelastic potting compound to the cer
tube and magnetic shield. The tests were made at 3200 g and were entirely succ
ful. The operational tube was operated in the camera tube test set at JPL befor
shocking. After completing several shocks of 3200 g, modified square wave, th
filament opened. This particular tube did not have the new filament constructio
the failure was not unexpected. Further tests will be done at JPL in the near fu
in addition to the shock testing being done at RCA.

The program is on schedule and is now approximately 80% complete. A f
the RCA plant in March has caused a delay of one month in the program. The p
type is now scheduled to be delivered in mid August. Figure 5 shows the revise
schedule.

'ollow-On Contract

The remainder of the funds not used during the present contract, combined with unds for FY 1967 total $154,000. Negotiations are presently under way to extend the ontract an additional 11 mo. RCA's proposal for the follow-on program is roughly 143,000, so no funding problems are anticipated for FY 1967.

The objectives of the new program are those as set forth in Paragraph B in tatement of Work 3475B dated 2 June 1966:

1. Attainment of a higher level of confidence in the ability of the vidicon to survive the dry-heat sterilization and ethylene-oxide decontamination requirements, according to JPL specification VOL-50503-ETS (Voyager requirements), and in the vidicon's capability to withstand the static acceleration, vibration, and shock conditions specified in the new Statement of Work.

2. Characterization of the physical, electrical, and imaging properties of the vidicon under development, with emphasis on the development of suitable test and acceptance criteria, useful in further development and future manufacture of the tube.

3. Advancement of the "state-of-the-art" of ceramic-and-metal tube construction, focus and deflection systems, and ruggedization of tube components, potting, and magnetic shielding.

'he basic program will consist of the development of an improved tube design based n the vidicon resulting from the initial phase of Contract 950985. The areas of work 'ill include the ceramic-modular tube envelope, focusing and deflection, mesh, lectron gun, and magnetic shielding and potting.

'UBLICATIONS DURING FY 1966

None.

'UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

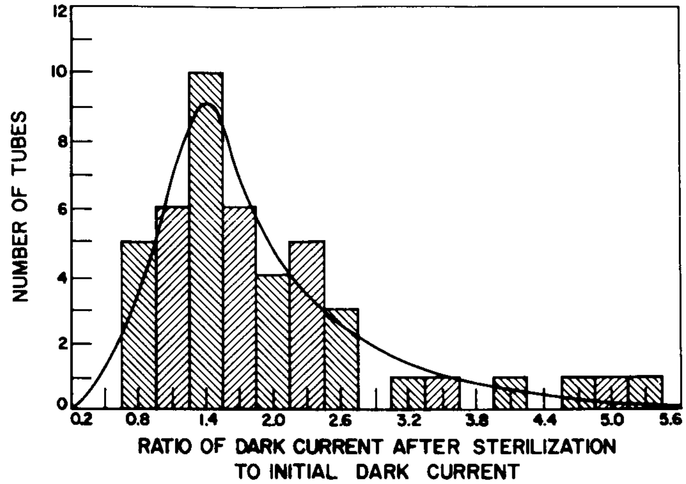


Fig. 1. Distribution of tubes in terms of dark current after sterilization to initial dark current (target voltage = 20 v)

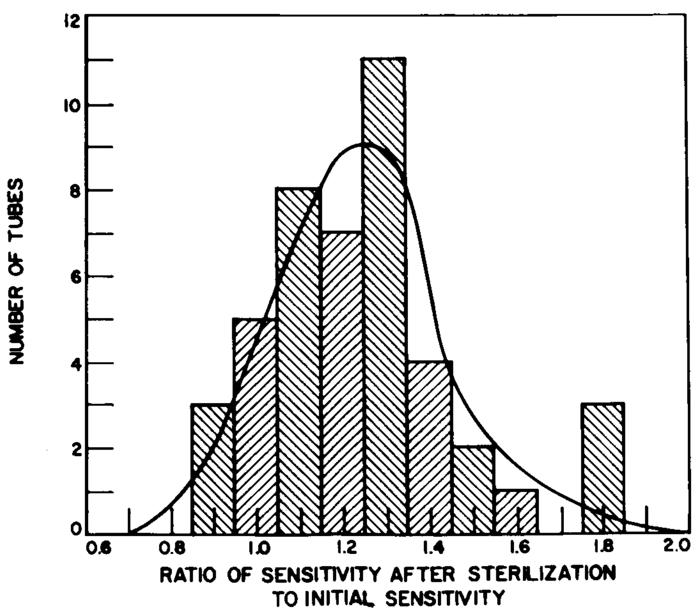


Fig. 2. Distribution of tubes in terms of sensitivity (signal current at 1.0-ft-cd target illumination) after sterilization to initial sensitivity (target voltage = 0.2 μamp)

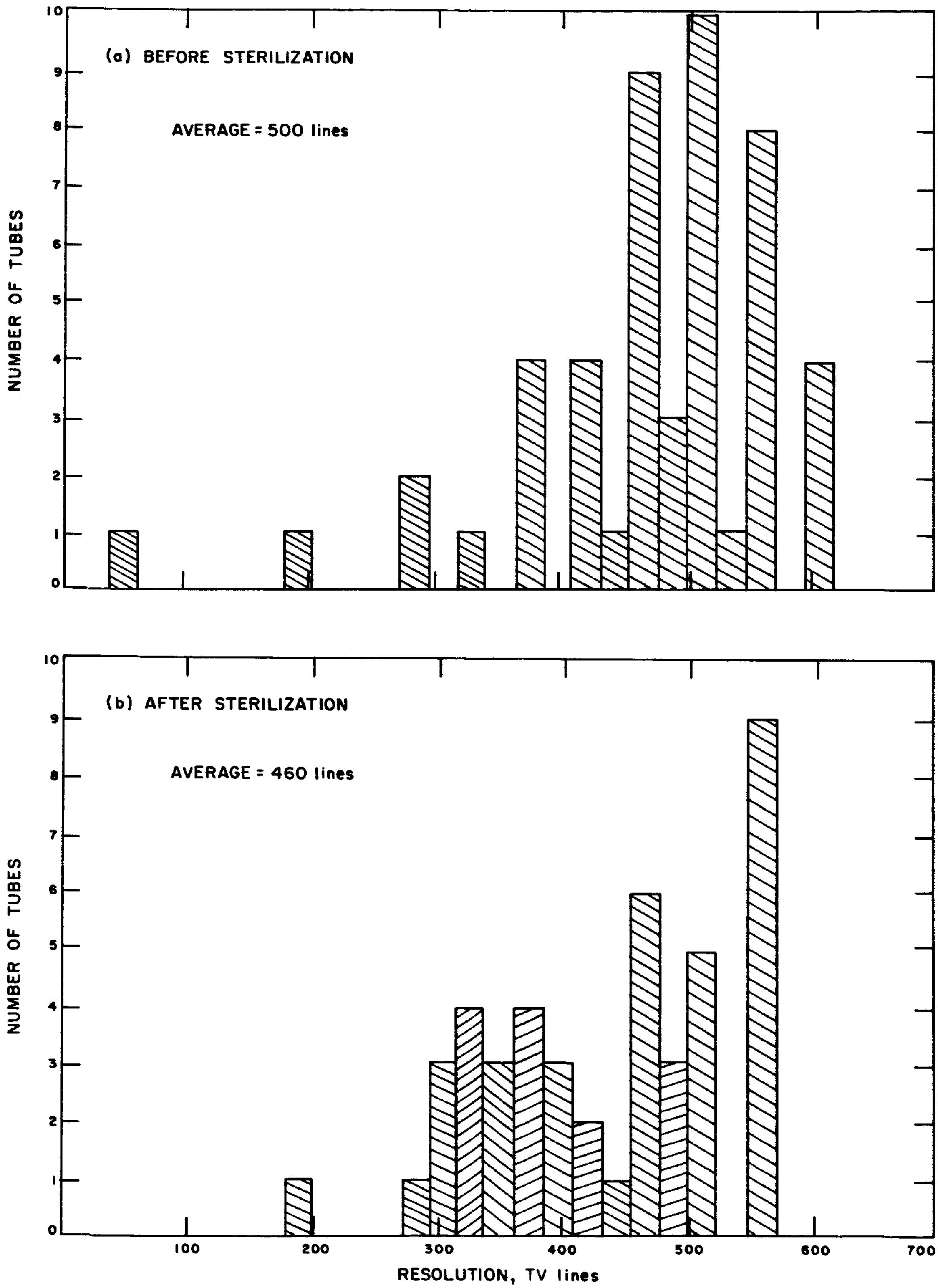


Fig. 3. Distribution of tubes in terms of resolution (target voltage = 20 v; signal current = 0.2 μamp)

Fig. 4. Complete ceramic vidicon

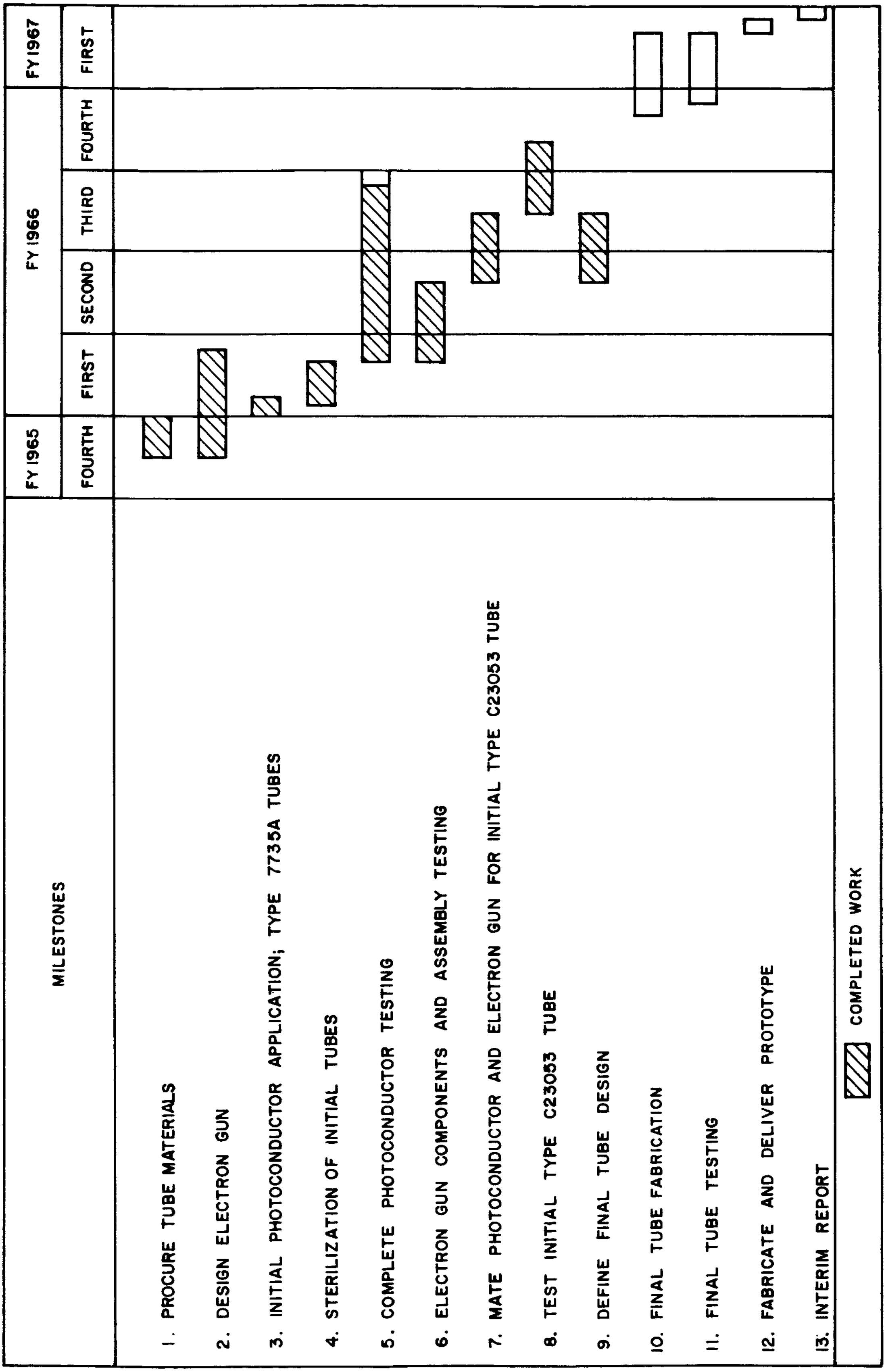


Fig. 5. Milestone chart for image sensor

REED-CAPACITOR-MODULATOR STERILIZATION

NASA Work Unit 186-58-06-04-55
JPL 384-84401-2-3220
J. R. Locke

OBJECTIVE

The primary objective is to develop a miniaturized modulator capable of converting low-level direct current (as low as 10^{-15} amperes) into a proportional sinusoidal voltage. Having nominally achieved this result the present effort is directed toward a threefold purpose: (1) to substantiate the effectiveness of the production technology developed in an earlier JPL contract (950668) in overcoming the problem of contact potential drift in the capacitor-modulator due to repeated sterilization cycles, (2) to substantiate the ability of the device to survive Voyager heat and ETO sterilization exposures, and (3) to insure the existence of an organization capable of building the Reed-Capacitor-Modulator for future needs.

STATUS REPORT

Following a literature search and industry inquiry, to insure that the subject device had not become obsolete due to state-of-the-art advances, action was taken to prepare a request for proposal to solicit organizations capable of building ten capacitor-modulators. The target date for execution of this contract was June 4, 1966. The Statement of Work prepared for the tentative contract projected a completion date of October 30, 1967. Because the cognizant technical representative was diverted into a more pressing flight project, the execution date on this contract has been delayed. It is presently intended that the request for proposals will be issued in early July 1966.

The proposed contract will be broken into three phases. Phase I is intended primarily to familiarize the contractor with the device, during which time only one unit will be built to relatively relaxed standards. Phase II will emphasize more stringent functional requirements on the one unit that will be built during this period. Phase III will incorporate all the functional specifications of phases I and II plus Voyager heat and ETO survival requirements.

PUBLICATIONS DURING FY 1966

JPL Technical Report

1. JPL Spacecraft Sterilization Technology Program; A Status Report, JPL TR 32-853, sec. VD, pp. 59-61 by J. R. Locke, December 31, 1965.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

SENSOR STERILIZATION AND TEST PROGRAM
NASA Work Unit 186-58-06-06-55
JPL 384-84601-2-3220
R. A. Wengert

OBJECTIVE

The purpose of this program is to provide data and useful information which will prove the availability of the following sterilizable, ruggedized, and highly reliable components: (1) Geiger-Mueller tubes, (2) solid-state radiation detectors, (3) inorganic scintillation crystals, (4) photomultiplier tubes, and (5) optical letector-scintillation crystal assembly. To accomplish this, development contracts are being monitored and the developed components are being tested to verify the nanufacturers' production capability, prove the design reliability, sterilizability, and usefulness of the items.

GEIGER-MUELLER TUBES

The contractor has completed the investigation of methods of internal surface protection. The final report has been received and the tubes developed during the contract will be shipped early in the first quarter of FY 1967. The results of the program are very encouraging in that any changes which are experienced as a result of the sterilization process are an improvement in the tube characteristics. The objective of the program was to obtain a relative plateau slope of no greater than 5% per 100 v. The average value obtained was 4.5%, the range of values being from ess than 1 to 8% with the majority below 5%. Although there are other approaches which may be taken to further improve the tubes, it is believed that no additional work need be undertaken at this time.

SOLID-STATE RADIATION DETECTOR

No additional development work has been started on this task since the final eport of the basic contract was received. The proposal for follow-on effort has been valuated and a statement of work prepared. A contract will be negotiated early in 'Y 1967 to undertake the development of surface protection, improved signal contact, nd detector packaging.

NORGANIC SCINTILLATION CRYSTALS

All sterilization testing has been completed with very minimal changes in the haracteristics. The changes experienced can, in most cases, be attributed to xperimental error and instrumentation accuracy. The environmental testing will be ompleted and the final report received in the first quarter of FY 1967.

'HOTOMULTIPLIER TUBES

A contract has been negotiated to further improve the electrical characteristics f the tube. It is believed that a more sensitive and stable photocathode can be proessed. No additional work need be done with the packaging since all environmental ests were successfully passed.

OPTICAL DETECTOR-SCINTILLATION CRYSTAL ASSEMBLY

A testing program has been completed to obtain data on silicon detectors whic are sensitive to the light which is emitted by scintillation crystals. A package is n being prepared to obtain maximum coupling between the crystal and detector. Whe: this task has been completed, the electronics will be optimized to obtain readable signals for all radiation stopped by the crystal.

FOLLOW-ON TEST PROGRAM

The difficulties which were encountered with the equipment used for testing tl Geiger-Mueller tubes have been overcome. An external discriminator circuit has been placed between the tube being tested and the scaler. The discriminator in the instrument received erroneous signals because the instrument amplified and overwhelmed the signal before being introduced into the discriminator. An additional quantity of tubes has been received and the test data agree quite well (considering the randomness of a radioactive source) with that of the manufacturer.

The test console for the solid-state radiation detectors has been installed anc is in use. The results obtained indicate a considerable change from that of the con tractor. Retest on the contractor's equipment indicated the same change. Surface contamination was suspected, and after the detectors were dried at 125°C for 10 min, the characteristics returned to normal value. This evidence further show the need for the follow-on effort, which will be started during the first quarter of FY 1967.

PUBLICATIONS DURING FY 1966

JPL Technical Reports

1. JPL Spacecraft Sterilization Technology Program; A Status Report, JPL TR 32-853, Sec. VF, pp. 62-65, by R. A. Wengert, December 31, 1965

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

STERILIZABLE CAPSULE DATA BUFFER
NASA Work Unit 186-58-06-07-55
JPL 384-84701-2-3240
R. H. Nixon

OBJECTIVE

The objective of this task is to develop buffer and random access memories with particular emphasis on sterilizability, impact resistance, low-power NDRO operation, and general reliability.

PROGRESS

Contract 950986 was initiated with the Librascope Group of General Precision, Inc., in Glendale, California, on April 1, 1966. The contract covers the first of two phases which will result in a breadboard system using a woven plated wire memory plane. The breadboard will be a 256-word, 16-bit version of the 512-word, 20-bit prototype system to be completed under a phase II contract.

Progress under the breadboard contract includes:

1. 75% completion of circuit design.
2. Completion of breadboard packaging layout.
3. Investigations of potting compound for the memory array.

Temperature cycling at sterilization temperatures has been conducted on the woven wire memory plane, while encapsulated with different compounds. Preliminary results indicate the memory plane will not be degraded after temperature cycling when encapsulated with a silicone rubber compound. Further testing is in progress. The breadboard phase is scheduled for completion in September 1966 at which time a thorough review will be conducted before proceeding to the flight prototype phase.

Figure 1 is a milestone chart showing the progress and planned objectives under the Librascope contract. The prototype development is phase II of the current contract. The phase II effort will be renegotiated based upon the results of the breadboard evaluation.

Figure 2 shows a woven plated wire memory plane that is similar to the one used by Librascope in the breadboard system. The vertical wires which can be seen extending from the weave are the plated bit lines. The insulated copper word lines are orthogonal to the bit lines and can be seen soldered to the printed circuit board at either end.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

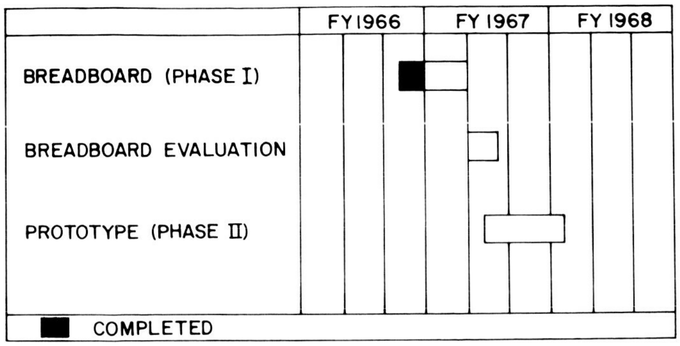


Fig. 1. Capsule memory system development

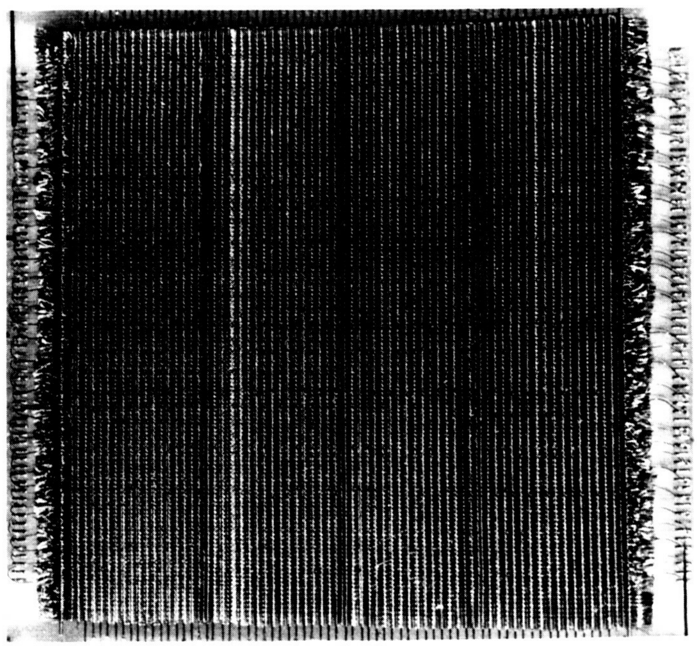


Fig. 2. Woven plated wire memory plane

STERILIZABLE SOLID ROCKET DEVELOPMENT
NASA Work Unit 186-58-08-01-55
JPL 384-81901-2-3810
C. Robillard

BJECTIVE

The long-range objective of this task is to understand and solve the engineering roblems involved in supplying solid propellant rocket motors for those planetary xploration spacecraft that will have to be sterilized to assure planetary quarantine.

ACKGROUND

Very early in the program, it was found that two propellants developed and upplied by industry offered some promise of withstanding thermal sterilization. hese were (1) a relatively hard propellant based on an ammonium perchlorate olyester-styrene copolymer, which was most applicable if the charge was to be a artridge design, and (2) an elastomeric propellant based on ammonium perchlorate oly(butadiene-acrylic acid) - imine binder, (PBAA-MAPO), which was more appliable for case-bonded motors.

Early thermal sterilization tests were performed at 295° F. More recently, e sterilization temperature has been changed to 275° F. The current effort is rected towards demonstrating the successful operation of a solid propellant motor ter 6 cycles of 53 hr duration at 275° F.

EAT STERILIZABLE MOTORS

Major emphasis is being given to the preparation of a small flight-weight motor assure that the real motor problems are recognized and solved. Since hardware r a 12-in. diameter, 60-lb Syncom flight motor (See Fig. 1) is available and is of a nvenient size, it is being used.

Under a JPL contract, the Naval Ordinance Test Station is investigating exoermic thermal degradation (or bulk cook-off) of heat sterilizable propellants. This primarily a safety study and the results will be used to predict the maximum prollant web thickness as a function of sterilization temperature. The first motor st performed under this contract has been completed. The motor consisted of a ncom case filled with X-6 (PBAA-MAPO) propellant in the standard Syncom grain sign. Mechanical properties of X-6 propellant are shown in Table 1. The temperure cycles in the NOTS test were not of standard length or temperature since the st was made primarily to investigate cook-off, not heat sterilizability. In the first cle alone, the propellant spent about 170 hr at 267 to 280° F. In all 4 cycles, the opellant spent approximately 400 hr at 267 to 280° F. With respect to thermal stality, the X-6 propellant survived the first 3 "cycles" (approximately 360 hr at 267 280 °F) without signs of degradation. Bulging occurred sometime during the urth "cycle". With respect to mechanical integrity, both radial and circumferenal cracks were found after the first test. Both cracks were tensile failures. The rcumferential cracks, which occurred at points of local stress concentration, can obably be eliminated by minor changes in grain design at the grain port-to-case nction. Radial cracks can be eliminated by one or more of the following:

1. Improvements in propellant elongation at 72 to 275° F.

2. Lower rates of cooling (this motor was removed from the oven at 275° F directly into storage at 72° F).

3. Changes in grain design; i. e., remove head-end star geometry, create slots, or decrease web fraction. The standard Syncom gra design has a web fraction of 0.65. For a capsule deflection motor the most desirable web fractions, ballistically, are less than 0.5

PROPELLANT DEVELOPMENT AND EVALUATION

Thermal Stability Evaluation

High-temperature vacuum stability tests using very small samples and bulk sterilization tests using 3- to 5-lb propellant charges have been used to measure a compare propellant thermal stability. Both the vacuum stability tests and the bull tests show that thermal stability is a strong function of temperature in the range 2 to 300° F. In bulk tests, PBAA-MAPO propellants, including X-6, survive the equivalent of six to nine 53-hr cycles at 275° F, but only three to four 36-hr cycles at 295° F.

Vacuum stability tests indicate that propellants based on carboxyl-terminate polybutadiene/imine binders (CTPB-MAPO) are significantly more stable at 275° I than are propellants based on PBAA/MAPO binders. Bulk stability tests are in progress.

Mechanical Integrity

The consulting services of Dr. A. Durelli have been obtained as an aid in stress analysis and grain design. Several new grain designs will be tested in the Syncom hardware.

Propellant Development

The propellant development effort is continuing with CTPB propellants. Mechanical properties of some recent formulations are shown in Table 1. Vacuu stability and bulk sterilization tests of the more promising formulations are in progress.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

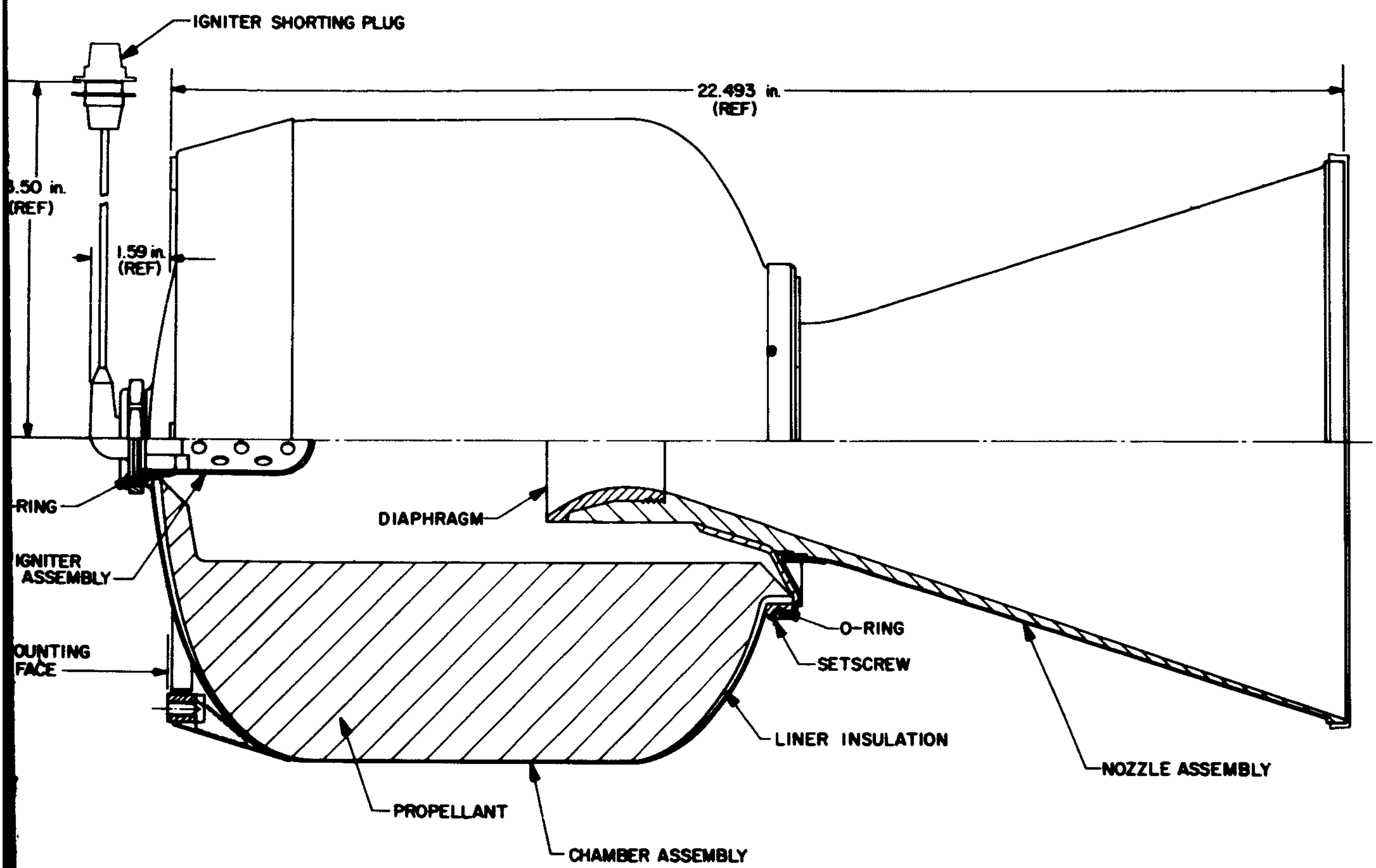


Fig. 1. Cross-sectional drawing of flight-weight SYNCOM motor

STERILIZABLE PROPULSION SYSTEM DEVELOPMENT

NASA Work Unit 186-58-08-02-55
JPL 384-82101-2-3840
D. D. Evans

BJECTIVE

The objective of this work unit is to develop the technology required for the use f sealed, ethylene oxide-compatible, heat-sterilizable liquid propulsion systems. uch systems will be required for probes or capsules that enter planetary atmos-heres. The liquid supply system technology will also have application as a mono-ropellant supply system for a turbo-alternator auxiliary power unit driven by aseous products from hydrazine decomposition.

ONTRACT STATUS

This work will be handled primarily by an industry contractor. The contractor ill conduct a design and experimental investigation and perform a feasibility demon-tration of a sterilizable liquid bipropellant propulsion system. To conduct this pro-ram he will be responsible for the design of an integrated, modular bipropellant ystem, the design and/or procurement of the required component parts, the testing these parts to determine their compatibility with heat cycling, and the assembly of ie component parts into a complete system, followed by both ethylene oxide expo-ıres and thermal cycling. Finally, a demonstration firing of the sterilized system ill be conducted with the system examined for possible adverse effects.

During this period the work statement was finalized and an RFP was issued to ıdustry. A response was received from eight major propulsion and prime contrac-rs. A contractor has been selected to perform the work and the contract is now nder negotiation. It is anticipated the work will begin approximately September 1, 966.

UBLICATIONS DURING FY 1966

None.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

STERILIZABLE PYROTECHNIC DEVELOPMENT

NASA Work Unit 186-58-12-01-55
JPL 384-82301-2-3810
Anthony G. Benedict

BJECTIVE

The objective of this task is to develop a small ceramic-header 4-pin onmagnetic squib capable of withstanding heat sterilization.

TATUS

Prototype squib bodies (718 Inconel) and ceramics are on hand. Headed pins ave been ordered; on receipt these will be used for evaluation of pin to ceramic eals.

A contract for a deposited-film development program has been negotiated with nidynamics Corporation. A bayonet-type coupling for a small squib connector has een evolved in-house; delivery of 100 prototype connectors is expected by October 966. Although encouraging results with developmental anti-static shunts using silion carbide powder in a silicone RTV matrix have been obtained, this effort has been scontinued for the present because of insufficient manpower.

In-house tests of primers using G-11 and G-16 percussion primer mixes in mbination with test results obtained informally from Frankford Arsenal indicate at these mixes are suitable for use in thermally sterilizable percussion primers, d that anomalous results in tests reported by a private company in 1964 are almost rtainly due to failure to confine the primers, firing pin eccentricity, inadequate ring-pin energy, or some such oversight which does not reflect on the primer liability.

Lack of manpower has forced the suspension of the informal evaluation tests of pollo Standard Initiators." The only significant weaknesses detected in these tests date are:

1. The squib bodies are magnetic as expected.
2. Three bridges (of 30 pairs tested) open-circuited during severe temperature shock tests; the bridge welds were found to have parted.
3. The squibs were found to be sensitive to static discharge under reduced atmospheric pressure, as expected.

The silicone resin varnish used as a binder in the proposed zirconium-based atch-head has been found to give a non-uniform porous texture, probably contribut- g to spread in firing characteristics. Work on selection of an epoxy or some alterte has been suspended because of staff shortages.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

ESTABLISH AN APPROVED LIST OF HEAT-STERILIZABLE ELECTRONIC COMPONENT PARTS

NASA Work Unit 186-58-13-01-55 (818-01-06-70-10*)
JPL 384-80101-1-1520

J. Visser

BJECTIVE

The objective of this task is to support the NASA thermal sterilization policy by tudying the effects of the thermal sterilization environment on the reliability of lectronic piece parts during long life. The study will result in the establishment of list of electronic piece parts capable of operating reliably for a minimum of 0,000 hr after being subjected to heat sterilization.

ROGRESS OF TEST PROGRAMS (see Fig. 1)

. ZPP-2101-GEN., Capacitor Test Follow-on (Preston Scientific)

The 16,000-hr measurements have been completed. The contractor's final report has been received. The JPL final report is scheduled for release during August 1966. In general, there were no significant degradation due to heat sterilization.

ZPP-2108-GEN., Capacitor Continuation Test (Mid-Continent)

Mid-Continent Laboratories was selected to perform the test program. The test program is scheduled to begin during July 1966. This is approximately a 2-yr effort.

ZPP-2102-GEN., Fixed Resistor Test (Preston Scientific)

The JPL final report is being prepared with a July 1966 release date. In general, all of the resistors were compatible with heat sterilization except the Allen Bradley 1/10-w carbon composition type. Consequently, this part type will not be included in the JPL Preferred Parts List.

Follow-on

The 14,000-hr measurements are in progress. To date no unusual events have occurred during the Follow-on Test. The Follow-on Test is scheduled to be finished during October 1966.

ZPP-2112-GEN., Fixed Resistor Continuation Test (Mid-Continent)

Mid-Continent Laboratories was selected to perform the test program. The test is scheduled to begin during July 1966. This is approximately a 2-yr effort.

*Transferred to Voyager Project in FY 1966.

5. ZPP-2103-GEN., Trimming Resistor Test (Boeing Co.)

The JPL final report is scheduled for release during July 1966. In general, there were considerable failures due to manufacturing defects, but there was no significant degradation due to heat sterilization.

6. ZPP-2109-GEN., Trimming Resistor Continuation Test (Mid-Continent)

Mid-Continent Laboratories was selected to perform the test program. The test is scheduled to begin during July 1966. This is approximately a 2-yr effort.

7. ZPP-2104-GEN., General Diode Test (Boeing Co.)

Life testing is scheduled to start during July 1966. The parts are now undergoing environmental tests. No unusual events have occurred to date.

Follow-on

The contract is scheduled to be awarded to Boeing during July 1966. This is approximately a 2-yr effort.

8. ZPP-2105-GEN., Varactor Diode Test (Microwave Assoc.)

The contractor's final report has been received. The JPL final report is scheduled to be released during September 1966. In general, there was no significant degradation due to heat sterilization.

9. ZPP-2106-GEN., Varactor Continuation Test

The original specification has been modified to replace one of the four varac diodes with a tunnel diode. The RFP is scheduled to be sent out during June 1966. The test program should start during September 1966. This is appro mately a 2-yr effort.

10. ZPP-2107-GEN., Fuse Test (Wyle Labs.)

All of the environmental testing has been completed. Life testing is schedu to begin during July 1966.

11. ZPP-2110-GEN., Thermistor Test (Sperry Utah)

The computer program is being debugged. The initial measurements are scheduled to begin during July 1966.

12. ZPP-2113-GEN., Transistor Test (Motorola)

The 4,000-hr measurements have been completed. The parts are at the 4,100-hr period in life testing. To date there has been no significant degra tion due to heat sterilization.

Follow-on

The contract has been modified to add 14 new state-of-the-art transistors to the test program. The follow-on test is scheduled to begin during July 1966. This is approximately a 2-yr effort.

3. ZPP-2116-GEN., Crystal Test Phase I (Philco WDL)

Philco WDL was selected to perform the test program. The test is scheduled to begin during July. This is approximately a 1-yr effort.

4. ZPP-2119-GEN., Relay Test (Sperry Utah)

The contract has been awarded to Sperry Utah. The test program has started and the test fixtures and equipment are being fabricated. Initial measurements are scheduled to begin during July 1966.

5. ZPP-2121-GEN., Digital Microcircuit Test (JPL)

The 8,000-hr measurements are in progress. The test program is scheduled to be completed during October 1966. There have been considerable failures due to manufacturing defects, but there has been no significant degradation due to heat sterilization.

ZPP-2122-GEN., Linear Microcircuit Test (JPL)

The measurement equipment is being fabricated. The initial measurements are scheduled to begin during July 1966.

ZPP-2124-GEN., Inductor Test (Philco WDL)

All of the environmental tests have been completed. Life testing is scheduled to begin during July 1966. The potting material on some transformer types was degraded by heat sterilization. This problem is being investigated.

ZPP-2126-GEN., Temperature Gradient Test (Preston Scientific)

The JPL final report has been released. In general, the temperature gradient between the interior and exterior of electronic component parts should not be a problem during heat sterilization, due to the long time of the exposure (approximately 92 hr).

ZPP-2118-GEN., Ethylene Oxide Test - Phase II Boeing Co., TRW, and Hughes Aircraft

The final reports have been received and are being evaluated. The better recommendations from all three reports will be consolidated into a JPL test specification for phase III. Phase III is intended to verify the conclusions of phase II by an actual test program.

20. ZPP-2125-GEN., Screening Development Program (Task I)

This program is intended to recommend screening methods so as to improve the reliability of component parts that will be exposed to heat sterilization. This is to be accomplished by making a design appraisal of various componer parts. The program is scheduled to begin during July 1966. This is approxi mately a 1-yr effort.

21. ZPP-2128-GEN., Hi-G Shock Program (JPL)

This program is intended to evaluate degradation of component parts when subjected to high-g shock (10,000 g). There will be an exploratory effort at JPL prior to contracting the main test program. The JPL effort is schedule to begin during July 1966.

22. ZPP-2123-GEN., Microcircuit Continuation Test (Litton)

Litton Industries has been selected to perform the test program. The test is scheduled to begin during July 1966. This is approximately a 2-yr effort.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. Martin, K., "Investigation of Ethylene Oxide Effects on Component Parts - Phase II," SPS 37-40, Vol. II, June 1966.

2. Martin, K., "Temperature Gradients within Component Parts when Exposed Heat Sterilization," SPS 37-38, Vol. II, February 1966.

3. Evans, K., "Variable Trimming Resistor Sterilization Test Program," SPS 37-39, Vol. II, May 1966.

4. Marlett, C., "The JPL Digital Microcircuit Sterilization Test Program Results (2,000 Hour Report)," The ECRC Tri-Annual Meeting, February 23, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

JPL SPS Contributions

1. Lee, H., "Varactor Diode Sterilization Test Program Summary," (outline being prepared).

2. Lee, H., "Capacitor Sterilization Test Extension Summary."

3. Martin, K., "Transistor Sterilization Test Program Summary (2,000 Hour Report)," scheduled for November 1966 release date.

4. Evans, K., "Resistor Sterilization Test Program Summary," scheduled for November 1966 release date.

Hopkins, T., "Hi-Impact Shock Program for Electronic Component Parts Interim Report Summary," scheduled for September 1966 release date.

Paquette, P., "Microcircuit Application Notes Summary," scheduled for July 1966 release date.

Paquette, P., "Transformer Sterilization Test Program Summary (2,000 Hour Report)," scheduled for December 1966 release date.

COMPLETE FAMILY	SPECIFICATION ZPP-GEN	SPECIFICATION IN PREPARATION	SPECIFICATION COMPLETED	CONTRACT NEGOTIATION AND APPROVAL	CONTRACT AWARDED	VISUAL INSPECTION	TEST EQUIPMENT AND FIXTURES	INITIAL MEASUREMENT	STERILIZATION TEMPERATURE CYCLING AND MEASUREMENT	ENVIRONMENTAL TESTING AND MEASUREMENT	START LIFE TEST	100-hr MEASUREMENT	250-hr MEASUREMENT	500-hr MEASUREMENT	1000-hr MEASUREMENT	2000-hr MEASUREMENT	4000-hr MEASUREMENT	6000-hr MEASUREMENT	8000-hr MEASUREMENT	10,000-hr MEASUREMENT	250-hr FOLLOW-ON MEASUREMENT	FINAL REPORT	CONTRACT CLOSED OUT	COMPLETED HOURS OF LIFE TESTING
CAPACITORS	2101																					▽		*16,000
(CONTINUATION)	2108			△																				—
FIXED RESISTORS	2102																					△		*14,000
(CONTINUATION)	2112			△																				—
TRIMMING RESISTORS	2103																					△		10,000
(CONTINUATION)	2109			△																				—
VARACTOR DIODES	2105																					△		10,000
(CONTINUATION)	2106			△																				—
GENERAL DIODES	2104									▽														—
TRANSISTORS	2113																△							4,100
DIGITAL MICRO	2121																	▽						8,000
(CONTINUATION)	2123			△																				—
FUSES	2107																							—
CRYSTALS	2116			△																				—
RELAYS	2119					△																		—
MAGNETICS	2124										△													—
THERMISTORS	2110						▽																	—
HIGH-g SHOCK	2128	△																						NA
ETO	2118																					△		NA
LINEAR MICRO	2122						△																	—
SCREENING	2125			△																				NA
TEMPERATURE-TIME TEST	2127	△																						—

△ IN PROGRESS
▽ COMPLETED
* FOLLOW-ON LIFE TEST OF CRITICAL TYPES
NA NOT APPLICABLE

STERILIZABLE POLYMERS

NASA Work Unit 186-58-13-02-55
JPL 384-83801-2-3510

Donald P. Kohorst

BJECTIVE

The long-range objective of this work unit is to determine the effects of hylene-oxide-decontamination and thermal sterilization on spacecraft polymeric oducts. The objective during this fiscal year was to evaluate previously used oducts (on Ranger and Mariner) that were exposed to the ethylene-oxide and theral treatments contemplated for the Voyager Project.

TRODUCTION

Early work in the program was concerned with the evaluation of polymeric oducts that were exposed to the 2-cycle, 24-hr ethylene oxide treatment and the cycle, 145°C thermal treatment described in Ref. 1 and 2, respectively. Later the ogram was changed when new sterilization requirements were released by the oyager Project Office. These changes consisted primarily of revising the list of lymeric products under evaluation in light of the latest spacecraft requirements d switching to the Voyager type approval decontamination and sterilization exposure eatments as described in Ref. 3.

Both in-house and contracted work has been utilized to accomplish this proam. The early effort was divided between the Hughes Aircraft Company (JPL Conact 951003) and JPL's Polymer Research Section (382). Hughes did the evaluations aling with exposure to ethylene oxide and a combination of ethylene oxide and theral exposure. Polymer Research evaluated products after thermal exposure alone. e more recent work pertaining to the Voyager treatments is being done primarily der contract with backup support by the Polymer Research Section.

The approach used for evaluating polymeric products for the effects of ethylene ide and thermal exposure is very simple. Samples of each polymer are prepared o test specimens, exposed to the appropriate exposure treatment or combinations treatments and tested. Results are compared to data obtained on unexposed mples and the net changes determined. The amount of change dictates a product's mpatibility with the respective treatment. Tests used for evaluating include ighing, dimensional measurements, tensile strength, shear strength, adhesion, rdness, electrical properties, elongation impact resistance, and others as propriate to a given product.

OGRAM STATUS

Work done by the Polymer Research Section to evaluate 160 polymeric products r the effects of the 145°C thermal treatment (Ref. 1) was completed in March 1966. prerelease final report was given limited distribution in May 1966. Release of is report to the normal distribution for JPL TR has been delayed because of some tential legal problems associated with publishing data that may be derogatory to a anufacturer's product. However, the problem has been studied and a decision ade to distribute the report to the normal distribution.

Hughes completed all work on their contract in April 1966. A total of 65 products selected from the 160 products tested at JPL were evaluated for the effect of ethylene oxide exposure (Ref. 1) and a combination of ethylene oxide followed by heat exposure (Ref. 1 and 2). Complete results of this work was reported by Hughe in a report distributed in June 1966.

Now under way in the Polymer Research Section is the evaluation of 29 new products which have been exposed to the Voyager ethylene oxide and thermal treatments (Ref. 3). They have also, during this report period, equipped their laborato in accordance with the Voyager specification (Ref. 3) to handle the ethylene oxide exposure treatments.

A $92,300 contract is pending with Autonetics Division of North American Aviation, Inc., to expose 182 products to the Voyager treatments. This work is planned to commence on July 20, 1966.

RESULTS

In general, the information obtained by the Polymer Research Section and by Hughes Aircraft Company on products exposed to the ethylene oxide and thermal treatments given in Ref. 1 and 2 shows that all products tested suffered some chan in their properties. These ranged from slight and inconsequential to extensive and serious in some cases. However, most products were not seriously affected, at least not to the point where they are considered unserviceable. Thermal exposure proved to be considerably more degrading than ethylene oxide exposure. In most cases, the combination of ethylene oxide and thermal exposure had little more effe on properties than thermal exposure alone. Investigations by Hughes to better understand reactions between ethylene oxide and polymers showed that some types are capable of absorbing up to 8 wt % of gas when exposed to a 100% ethylene oxide atmosphere. However, when exposed to vacuum, all but a fraction of this gas was desorbed. This reversible physical adsorption was found to be the principal polym gas reaction.

FUTURE PLANS

During the next fiscal year, there is planned an in-house effort to evaluate polymeric products exposed to a higher temperature and a lower temperature steri ization treatment than previously investigated. The purpose is to obtain data at enough of the proposed NASA sterilization temperatures to enable the prediction of the optimum temperature for minimum damage to polymeric products. This work will be done on a select group of products which typically represent all product cat gories and polymer types. Evaluation will be based as before on changes to mecha ical and physical properties as compared before and after exposure.

In addition, new spacecraft products will continue to be evaluated for the effe of the Voyager treatments as the need requires.

REFERENCES

1. JPL Specification XSO-30275-TST-A, "Compatibility Test for Planetary Dry Heat Sterilization Requirements."

2. JPL Specification GMO-50198-ETS, "Compatibility Tests for Ethylene Oxide Decontamination Requirements."

3. JPL Specification VOL-50503-ETS, "Voyager Capsule Flight, Equipment, Type Approval and Flight Acceptance Test Procedures for Heat Sterilization and Ethylene Oxide Decontamination Environments."

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

1. Kohorst, Donald P., "Polymers for Sterilized Spacecraft," National Conference on Spacecraft Sterilization Technology, November 16-18, 1965.

Contractor Reports, Final

1. Rydelek, R. F., and Landis, A. L., Study of the Effects of Ethylene Oxide-Freon 12 Upon Properties of Polymers and Metallic Surfaces, Hughes Aircraft Co., Report No. P66-96, March 31, 1966 (JPL Contract 951003).

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

JPL Technical Reports

1. Kalfayan, S. H., and Campbell, B. A., Effects of Thermal Sterilization Procedure on Polymeric Products, TR 32-973, scheduled for release July 15, 1965.

STERILIZABLE ELECTRONIC EQUIPMENT PROCESSES

NASA Work Unit 186-58-13-03-55
JPL 384-85301-2-3570

R. F. Holtze

)BJECTIVE

The primary objective of this work unit is to develop and qualify sterilizable naterial applications and processes for assembling and packaging of electronic :quipment. This task will develop the required instrumentation for testing the pro- :ess applications, to evaluate known materials and process methods for sterilization :ffects, and then to test new materials and methods in the deficient areas until an .dequate set of sterilizable electronic assembly processes is obtained.

Supporting objectives include the following:

1. Measurement of pressures generated by various resin systems as a function of temperature and the development of a method of encapsulation which reduces these pressures to a safe limit.

2. The development of a subminiature pressure transducer which can be embedded permanently in a test module to monitor the pressure generated by the embedment material on the electronic components over an extended range of -120 to + 250°F.

:LECTRONIC EQUIPMENT PROCESSES

This work is being done under Contract 951214 by Northrop Space Laboratories nd covers investigations into four areas of interest:

1. Embedment of welded modules.

2. Conformal coating of printed wiring board assemblies.

3. Adhesive bonding of joints in electronic equipment.

4. Component lead strain relief for component mounting.

A contract modification was issued on May 31, 1966 to include determination of erilization effects occurring in the various modules as a result of exposure to two fferent sterilization treatments. The ethylene oxide exposure is similar for both eatments and consists of exposure to an ethylene oxide atmosphere maintained at)0 mg/l and 50°C for 3 cycles (30 hr per cycle). The heat sterilization for one roup of modules consists of exposure to 145°C for 6 cycles (36 hr per cycle) while second group is exposed to 135°C for 6 cycles (92 hr per cycle).

This modification used FY 1966 funds and increased the contract amount by :,699. Due to the longer sterilization time required, the contract completion date as extended to August 1, 1966.

The present status of the various subtasks is as follows:

Subtask 1 (Embedment of Welded Modules)

Difficulty was experienced in establishing reliable weld schedules for fabrication of the modules. This was primarily due to (1) the large variety of lea materials involved and (2) difficulty in welding the nonmagnetic material (Alloy 90 used for interconnections. Satisfactory weld schedules have been developed and t first group of six modules fabricated and embedded in two different materials. These modules are to be sterilized and effects determined prior to embedment of the remaining ten modules.

Subtask 2 (Conformal Coating of Printed Wiring Board Assemblies)

All modules have been fabricated and operating parameters of the componen determined after fabrication. These modules will be sterilized concurrently with modules from subtasks 1 and 3 and effects of sterilization determined.

Subtask 3 (Adhesive Bonding of Metal and Plastic Surfaces)

All modules have been fabricated and will be sterilized and tested concurre with modules from subtasks 1 and 2.

Subtask 4 (Strain Relief of Component Leads)

All modules have been fabricated. Difficulty was encountered in bonding of miniature strain gages to the component leads but a satisfactory method has now been developed. These modules are presently undergoing heat sterilization with strain gage data being automatically recorded.

Future Plans

Analysis of test results and determination as to the effectivity of the instru- mentation technique used will be performed after completion of sterilization expo tests and determination of changes occurring in operating parameters of the components.

Additional embedment and conformal coatings will be evaluated for suitabili of use in sterilizable electronic assemblies. This work will be accomplished du FY 1967 under the same task. The materials for evaluation will be selected fro those that have passed the tests conducted by the Materials Section under Work U 186-58-13-02 Sterilizable Polymers.

EMBEDMENT STRESSES IN EMBEDDED MODULES

The use of pressure calibrated mercurial thermometers to measure the pr sures generated at low temperatures in various resin systems used for encapsula has continued. As described in JPL TM 33-272, the thermometer was bonded in header and hydrostatically calibrated to pressures up to 7600 psi. Using the hea as part of the mold, the thermometer bulb was encapsulated in the resin system being evaluated and subjected to temperature runs. Monitoring the actual bulb temperature by means of a thermocouple, the resultant pressure effect on the bu can be measured.

xtension of Lower Temperature Range

The use of mercury thermometer bulbs embedded in resin systems for ressure measurement has the lower temperature limitation of -40°F, the freezing oint of mercury. To extend this lower limit using liquid filled thermometers equires the use of liquids with lower freezing points. Several thermometers with a ow temperature limit of -100°F, which were filled with pentane, were obtained and ressure calibration runs made. Because of the much larger coefficient of thermal xpansion of pentane as compared to mercury, the thermometer bore was much arger than for mercury thermometers. Since the change in volume due to the same ompressive forces is the same on the bulb regardless of the composition of the iquid, a larger bore will result in a smaller change in the reading. Calibration onstants of approximately 900 psi/°F were obtained, which is nearly ten times that f the mercury thermometer. Based on this information, the use of a liquid type hermometer measuring device below -40°F will not be successful unless a liquid an be found that (1) is suitable for use in a thermometer, (2) has a lower freezing oint than mercury, and (3) has a thermal coefficient of expansion comparable to ercury.

A few calibration runs of carbon composition and other types of resistors suit-ble for embedable pressure transducers have been made to 10,000 psi with reason-ble linearities shown. Measurements of the effects of temperature on such esistors have not resulted in a linear relationship which would lend itself to temper-ture compensation techniques. It would appear that the effects of temperature on ressure sensitive components would be almost as important as the linearity of the ressure versus resistance effect on such a component. Further work has been uspended due to lack of technician personnel.

uture Plans

Preparation of a final report and development of an extended temperature range ressure transducer will be completed under the Electronic Packaging Advanced evelopment Work Unit (NASA Code No. 125-25-03-01-55) in FY 1967.

UBLICATIONS DURING FY 1966

None.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

PL Technical Report

. Bunker, E. R., Jr., Development of Low Stress Encapsulent Systems by Improved Techniques of Stress Measurements Employing Mercurial Thermometers (rough draft is in progress).

STERILIZATION OF IMPACT LIMITERS

NASA Work Unit 186-58-13-04-55
JPL 384-85701-2-3510
D. P. Kohorst

BJECTIVE

The broad objective of this work unit is to evaluate promising impact limiter ıaterials for possible effects resulting from biological decontamination and steriliza-on procedures. The specific objective for this fiscal year's work was to evaluate ılsa wood for the effects of decontamination and sterilization treatments being con-dered for the Voyager Project. Initial efforts were directed toward a better defini-on of the problems associated with sterilizing this material with primary emphasis ı its energy dissipation properties.

CCOMPLISHMENTS

During this report period, balsa wood was evaluated for the effects of the latest oyager type approval decontamination and sterilization treatments as described in PL Specification VOL-50503-ETS. Briefly, these treatments consist of six 28-hr cles at 50°C in a mixture of 12% ethylene oxide--88% Freon followed by six 92-hr cles of heat at 135°C in a pure nitrogen atmosphere. A milder one-cycle treat-ent, at the above conditions, was also given to obtain data on the effects of a single cle exposure. In addition, several specimens were exposed to six cycles of the hylene oxide treatment alone. Energy dissipation capacity, expressed as specific ergy, was the primary property measured to ascertain any effects caused by decon-mination or sterilization. Weight and dimensional changes were also measured.

An experiment to study a technique for decreasing the heat-up time required for rge balsa wood impact limiters was also completed during this report period. though not originally planned for this work unit, it was undertaken to solve a prob-m caused by balsa wood's low thermal conductivity.

ESULTS AND DISCUSSION

Specific energy values obtained on wood exposed to the earlier described Voy-er treatments show that no gross changes take place. However, there is sufficient atter in the data to make the detection of small effects impossible. Visually, the ecimens were slightly tanned throughout with little difference in color between the ngle cycled and the six cycles specimens. Specimens exposed only to the ethylene ide-Freon mixture showed no color change.

This data disagrees somewhat with earlier data obtained at 145 and 125°C. The rlier data showed some degradation took place in energy absorbing ability when posed to heat; however, these exposures were in air while the recent ones were in re nitrogen. It is now believed that the presence of air during exposure causes gradation not found with pure nitrogen atmosphere.

The balsa wood heating experiment was based on an observation that balsa wood extremely permeable to gasses. Knowing the sterilization problem resulting from long heatup time required for large balsa wood impact limiters (estimated at 0 hr for 16-in.-thick limiter), it was apparent that passing hot nitrogen through the

material might be a solution. This was tried by passing 135°C nitrogen through a 16-in. -long block of wood fitted with special end closures to confine the flow of ga At a pressure differential of 2 to 4 psi across the 16-in. length, the nitrogen flow sufficient to heat the entire mass to 135°C in just over 3 hr. Leakage out the side the block was negligible. Therefore, it follows that by manifolding hot nitrogen in the center of the spherical impact limiter and allowing it to flow out through the na ral channels in the wood, it is possible to drastically reduce the heatup time requi for sterilization.

FUTURE PLANS

Because of a lack of manpower to continue this task, no further work is plan until the beginning of the third quarter of the next fiscal year. At that time, the e will be reactivated to obtain detailed design information for sterilized balsa wood to develop a better procedure for selecting wood in order to reduce the scatter in energy absorbing properties.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

JPL Technical Memorandums

1. Bernett, E. C., and Martens, H. E., Effects of Sterilization on the Energy Dissipating Properties of Balsa Wood (to be published in the first quarter of FY 1967).

STERILIZABLE ELECTRICAL SOLDERED AND WELDED JOINTS
NASA Work Unit 186-58-13-05-55
JPL 384-85001-2-3570
R. F. Holtze

)BJECTIVE

The long-range objective of this work unit is to determine the effects of terilization treatments on the various material combination joints that are soldered r welded for connections in electronic equipment and to develop improved joining ıethods or more compatible material combinations in the deficient areas.

Additional work will be done to investigate the metallurgical stability of typical elded joints between component leads and various candidate nonmagnetic intercon-ect materials. This work is part of a program for qualification of a nonmagnetic nterconnect material to be used for welded cordwood modules in a sterilization nvironment.

TERILIZATION EFFECTS TESTING OF SOLDERED AND WELDED JOINTS

Contract 951069 to the Hughes Aircraft covering an investigation of steriliza-on effects on soldered and welded joints was completed on November 9, 1965. This ork also included an investigation of sterilization effects on the solderability of var-ous lead materials. Results of this investigation are covered in Hughes Aircraft orporation Report P-65-117 (NASA Accession N 66-12854).

The test results indicated that sterilization caused no significant change in the ltimate strength, electrical resistance, or metallurgical properties of soldered or elded joints. However, the stress-rupture strength tests on wires soldered into onnector cups revealed that steady state loads of only 10% of the ultimate strength of ıe joint at room temperature were sufficient to cause short-term solder joint fail-res when tested at thermal sterilization temperatures of 145°C.

A Work Statement has been issued for an investigation of three high strength olders believed to have higher stress-rupture strengths at elevated temperatures. he solders selected are in accordance with QQ-S-571d and consist of Sn 96 (tin 96% nd silver 4%), Sn 62 (tin 62%, silver 2%, and lead 36%) and Sb 5 (tin 94%, antimony %-6%, and lead .2%). These solders will be evaluated for (1) stress-rupture trength at sterilization temperatures, (2) ultimate strength, (3) electrical resist-nce, (4) metallurgical properties, and (5) application characteristics. The tests, here applicable, will be run before and after heat sterilization. The effects of heat terilization will be determined after exposure to a temperature of 135°C for 552 hr nd also after 145°C for 108 hr. In addition, the properties of Sn 63 solder after xposure to a sterilization temperature of 135°C for 552 hr will be determined and ompared with results obtained in the previous test conducted at 145°C for 108 hr.

A contract covering the above work is in the final stage of negotiations with ughes Aircraft Corporation and should be approved in the near future. This con-act will be funded with FY 1966 funds and will amount to approximately $16,000.

Future Plans

The investigation outlined above will be conducted during FY 1967 and results analyzed. The results of this investigation will determine future action but present plans do not anticipate any further work in determining sterilization effects on soldered or welded joints.

NONMAGNETIC INTERCONNECT MATERIALS

The supporting work toward identifying and qualifying a nonmagnetic weld inte connect material that is equal to, or better than, nickel in the essential welding characteristics was performed in the NASA Work Unit 125-25-03-01-55, Electronic Packaging Advanced Development. Although pure palladium and Alloy 90 (copper-nickel) appeared promising, the identification of a suitable nonmagnetic interconnec material has not been completed. For this reason the outside contract for the meta lurgical study of nonmagnetic welded interconnections described in this Work Unit h not been released.

The work on nonmagnetic interconnections started during FY 1966 in this Wor Unit is being transferred to NASA Work Unit 186-68-10-09-55, Modular Welded Packaging Advanced Development for a continuing effort during FY 1967.

PUBLICATIONS DURING FY 1966

Contractor Reports

1. Keister, F. Z., Determination of the Effects of a Thermal Sterilization Process on the Mechanical and Electrical Properties of Soldered and Welded Joints, Hughes Aircraft Corporation, Report P-65-117 Part I, October 9, 19((JPL Contract 951069; NASA Accession No. N 66-12854).

2. Keister, F. Z., Determination of the Effects of Thermal Bake-Out, Heat Sterilization and Ethylene Oxide Decontamination on the Solderability of Component Leads, Hughes Aircraft Corporation, Report P-65-117 Part III, October 9, 1965 (JPL Contract 951069; NASA Accession No. N66-12854).

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

STERILIZABLE CONNECTORS, WIRES AND CABLING ACCESSORIES

NASA Work Unit 186-58-13-06-55
JPL 384-85801-2-3570

W. R. Protich

BJECTIVE

The objective of this work unit is to determine the suitability of selected nulti-pin electrical and RF connectors, electrical wires and RF cables, and accesory connector and cabling components applicable to sterilizable spacecraft assemlies. Pertinent detail design specifications and test specifications have been repared as models to guide the development and testing activities.

LECTRICAL CONNECTORS

Appropriate changes have been drafted in the original JPL Request for Proposal 37176 - Effects of Heat Sterilization and Ethylene Oxide Decontamination On Elecrical Multi-Pin Connectors. These changes subject parts and components to more umerous type approval ethylene oxide (ETO) decontamination and heat sterilization ycles proposed by the Voyager Project. Test procedures were refined and consoliated to provide for more meaningful data but basically they remained the same. evisions were made in the work statement to reflect changes in the sterilization and esting procedures and provide for the submission of a detailed test plan by bidders. ask 2, which provided for a complete qualification test plan, was removed from the rogram and made a part of the 1967 Work Unit - Evaluation and Qualification Of onnector and Wire.

Candidate connectors selected for test contain sterilizable polymers which were etermined from the FY 1965 Sterilizable Polymer Task and the results of tests hich evaluated minimum requirements of volatile condensible material deposits in a pace environment. These connectors are included in Table 1.

The electrical connector sterilization package was submitted for bid to eight ontractors selected from a master source list. These companies were sterilization riented and possessed the necessary capabilities and experience to accomplish the sk. Several of the bidders felt their sterilization facilities were inadequate to satfactorily perform the ethylene oxide decontamination tests. The remaining conactors declined to bid because of heavy work loads in military and space projects nd preferred not to take on additional commitments.

The multi-pin electrical connector package will be combined with the wire, abling accessories, RF connector, and RF cable package to form a single new sterization package for 1967. This would eliminate considerable duplications of testing ffort and provide for economies in testing costs. The work statement will be modied to permit the contractor to subcontract the entire ethylene oxide decontamination xposure or any portion thereof, and thereby eliminate a known impediment to bidding.

IRES, CABLING ACCESSORIES, RF CONNECTORS, AND RF CABLES

Changes were also made in the Request for Proposal 337388 - Effects of Heat erilization and Ethylene Oxide Decontamination On Wires, Cable Accessories. cluding Lacing Cords, Clamps, Insulation and Wire Terminations, RF connectors nd RF cables, in order to subject the subject parts and components to more

Table 1. Connector candidates

Configuration	Manufacturer	Insert Material
Circular	Bendix	Silicone Rubber
Circular	Microdot	Glass fiber/Diallyl
Circular	Deutsch	Glass (fused)
Rectangular	Deutsch	Glass (fused)
Rectangular	Deutsch	Glass fiber/Phenolic
Rectangular	Atlas	Glass fiber/Diallyl
Rectangular	Winchester	Glass fiber/Diallyl
Rectangular	Cinch	Glass fiber/Diallyl

numerous type approval ethylene oxide (ETO) decontamination and heat sterilizatio cycles specified by the Voyager Project. Test procedures were streamlined but nc fundamental changes were made. Task 2, qualification tests, were transferred to the 1967 Work Unit - Evaluation and Qualification Of Connectors and Wire. The wc statement was also revised to reflect changes in the sterilization and testing proce- dures, and to require a detailed test plan from bidders. Candidate parts and hook wire cables assembled with cabling accessories were selected for test based on sterilizable polymers which were determined from the FY 1965 Sterilizable Polym Task and on the results of tests establishing minimum requirements of volatile con densible material deposits in a space environment. These parts are included in Table 2.

Because of the disappointing response of bidders to the multi-pin electrical connector sterilization package, it was decided not to release the wire, cable acce sories, RF connectors, and RF cables package until modifications were made to th work statement. Such a modification would permit contractors to subcontract the ethylene oxide decontamination exposure. A subsequent decision to combine this package with the electrical connector package has resulted in the initial reorganiza tion of these programs toward economies in testing costs and elimination of duplica tion of testing efforts. Present plans for 1967 call for a single sterilization packag

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

Table 2.

Parts	Insulating Materials
Hookup Wire	Fluorocarbon (TFE) Kapton (H-Film) Polyamide Vinylidene Fluoride ML (Polyimide/Fluorocarbon) (FEP)
Winding Wire (Magnet)	Silicone Fluorocarbon (TFE) Ceramic Polyester Polyimide Polyurethane Nylon/Polyurethane
Form Wire (leads for Modular concept)	(No insulation) Conductors and Beryllco 25 Copper/Nickel, and Kovar
Insulation	Silicone Rubber Irradiated Modified Polyolefin Polyethylene Terephthalate Fluorocarbon (FEP)
Lacing Cords	Siliconized Dacron Rubberized Dacron Fluorocarbon (TFE) Fluorocarbon/Glass Dacron Nylon Silicone/Glass Rubberized Fluorocarbon (TFE)
Cable Clamps	Fluorocarbon (TFE) Nylon (Zytel 101) Silastic
RF Cables	Irradiated Modified Polyolefin Fluorocarbon (TFE) Fluorocarbon/Glass
RF Connectors	Fluorocarbon (TFE) Silicone

MATRIX TEST OF STERILIZABLE PIECE PARTS

NASA Work Unit 186-58-13-08-55
JPL 384-80401-2-3540
J. Visser

)BJECTIVE

The objective of this task is to support the NASA thermal sterilization policy y studying the temperature-time relationships of the sterilization environments as it ffects the reliability of some representative electronic component piece parts during ong life.

IATRIX TEST OF STERILIZABLE PIECE PARTS - TEST SPECIFICATION PP-2127-GEN

This test program is intended to evaluate temperature-time effects on the long-erm reliability of the parts outlined below.

Code	Part description	Manufacturer	Type	Quantity
1	Solid tantalum capacitor	Sprague Elect.	350D	720
2	Mylar capacitor	Aerovox	V423XP	720

Due to the complexity of the test program and the associated costs only two ypes of parts were selected for evaluation. The solid tantalum and mylar capacitors ere selected because of their susceptibility to degradation as evidenced from pre-ious heat sterilization tests.

The test program is outlined in Fig. 1.

The program is scheduled to start during August 1966. This is approximately 2-yr effort.

UBLICATIONS DURING FY 1966

None.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

ASSIGN SERIAL NUMBERS 1-720 FOR EACH CODE

MEASURE PARAMETERS, SCREEN PARTS FOR 168 hr WITH POWER APPLIED, REMEASURE PARAMETERS

START TEST PROGRAM

FOR EACH CODE, RANDOMLY SELECT 540 PARTS THAT PASSED THE SCREENING STEP.

FOR EACH CODE, RANDOMLY SELECT 30 PARTS FOR EACH GROUP (MATRIX CELL).

MEASURE PARAMETERS AND RECORD DATA.

TEST MATRIX

36 hr	GROUP A 30 PARTS (TYPICAL)	GROUP B	GROUP C	GROUP D	GROUP E	GROUP F
65 hr	GROUP G	GROUP H	GROUP I	GROUP J	GROUP K	GROUP L
94 hr	GROUP M	GROUP N	GROUP O	GROUP P	GROUP Q	GROUP R
	105 °C	115 °C	125 °C	135 °C	145 °C	160 °C

SUBJECT EACH GROUP TO THE ABOVE SPECIFIED CONDITIONS FOR ONE CYCLE. NO POWER APPLIED.

MEASURE PARAMETERS AND STATISTICALLY ANALYZE THE DATA. REPEAT THE TEMPERATURE EXPOSURE AND MEASURE PARTS - 5 TIMES

LIFE TEST PARTS AT 100 °C WITH POWER APPLIED. REMOVE PARTS, MEASURE PARAMETERS AND STATISTICALLY ANALYZE DATA AT 100, 250, 500, 1000, AND 2000 hr

PREPARE 2000-hr INTERIM REPORT

CONTINUE LIFE TEST, MEASURE PARAMETERS, MEASURE PARAMETERS AT 4000, 6000, 8000, AND 10,000 hr

PREPARE FINAL REPORT

Fig. 1. Matrix test of sterilizable piece parts

SPACECRAFT AND CAPSULE EQUIPMENT DEVELOPMENT (186-68)

PLANETARY ENTRY AND LANDING STRUCTURES

NASA Work Unit 186-68-01-01-55
JPL 384-60101-2-3530

A. C. Knoell

BJECTIVE

The purpose of this work unit is to study and develop the application of aterials and devices with high energy-dissipating capabilities to the protection of pacecraft and/or capsules during terminal landing. The broad objectives of this nit are twofold. First is the mathematical prediction of the response of energy dis-pators subject to material and system constraints, and second is the evaluation of ertinent energy-dissipating properties of various materials and devices. The cur-ent fiscal year objectives include the theoretical determination of stress wave fects on the response of energy dissipators and the evaluation of balsa wood, plastic oneycomb, and metal honeycomb as energy-dissipating media.

HEORETICAL RESPONSE PREDICTIONS

The phenomena associated with the impact of long one-dimensional bars into gid as well as elastic planar targets have been defined using the method of charac-ristics. The character of the solutions for bars having nonlinear stress-strain operties has been defined. Considered were the three general categories of: strain rdening, strain softening, and the rigid-plastic idealization. These results are ntained in a JPL Technical Report (see Publications During FY 1966).

Extension of the one-dimensional case to two and three dimensions is currently der study. The objective is to ultimately predict approximately the short-time havior of an impacting sphere. The continuing work is again based on use of the ethod of characteristics.

ATERIAL EVALUATION PROGRAMS

lsa Wood

An in-house development program designed to determine the physical and vironmental effects on the response of balsa wood as an energy dissipator has been mpleted. The results of this program, including a detailed description of test ecimens, equipment, instrumentation, and procedure are presented in a JPL chnical Report (see Publications During FY 1966). No further effort is contem-ated for the immediate future regarding additional development of balsa wood.

astic Honeycomb

A development program designed to improve the energy-dissipating character-ics of phenolic honeycomb and increase its double curvature capability is being nducted by the General Electric Company, Valley Forge, Pennsylvania, under L Contract No. 951172. Results of this program to date indicate that:

1. Use of new "high temperature" resins in the fabrication of honeycomb specimens does not increase the energy-dissipating capability of the

honeycomb over that of specimens fabricated with the standard phenolic resin system.

2. Substitution of paper in place of glass cloth as the honeycomb skel core causes a reduction of approximately 40% in the energy-dissipating capability of the honeycomb.

3. Resin cure temperature has a definite effect on the crushing stren of phenolic honeycomb in that the lower cure temperatures result lower values of specific energy dissipation.

4. A prefailed depth of approximately 0.3 in. is required to insure t the initial peak force will not exceed the quasi-steady-state crush force of phenolic honeycomb.

5. Use of a thin dip technique for resin buildup on the honeycomb gla cloth core is sufficient to preclude previously experienced failure the honeycomb at the node bond lines during static crushing.

6. As shown in Fig. 1, a maximum specific energy dissipation of approximately 19,200 ft-lb/lb (including thickness efficiency) can developed for phenolic honeycomb of approximately 12.5 lb/ft^3 density.

The effects of sterilization and high-velocity impact (500 ft/sec) on the resp of phenolic honeycomb should be determined during the first quarter of FY 1967. The double curvature capability of a phenolic "dovetail" honeycomb configuration should also be established at that time.

Owing to difficulties encountered in the fabrication of the dovetail configurat honeycomb, the contract completion date has been extended to November 1, 1966.

Aluminum Honeycomb

An RFP has been issued for the development of doubly curved aluminum hon comb as an energy dissipator. The honeycomb configuration to be investigated is known as "Flexcore," a product of the Hexcel Corporation, Berkeley, Calif. Thi configuration is readily formed into double curvature and is of sufficiently small size to have an adequate energy-dissipating capacity.

Responses to the RFP have been obtained and are currently being evaluated contract should be let during the first quarter of FY 1967.

PUBLICATIONS DURING FY 1966

JPL Technical Reports

1. Knoell, A. C., Environmental and Physical Effects on the Response of Bals Wood as an Energy Dissipator, TR 32-944, June 15, 1966.

nterim Contractor Reports

. General Electric, Development of Energy-Dissipating Plastic Honeycomb, Quarterly Progress Report No. 3, December 31, 1965 through March 31, 1966 (JPL Contract No. 951172).

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

apers to be Presented at Meetings or Symposia

. Knoell, A. C., "Physical and Environmental Effects on the Energy-Dissipating Characteristics of Balsa Wood," SAE 1966 National Aeronautic and Space Engineering Meeting, October 3-7, 1966.

PL Technical Reports

. Utku, S., On the Impact Induced Stress Waves in Long Bars, TR 32-932, July 1, 1966.

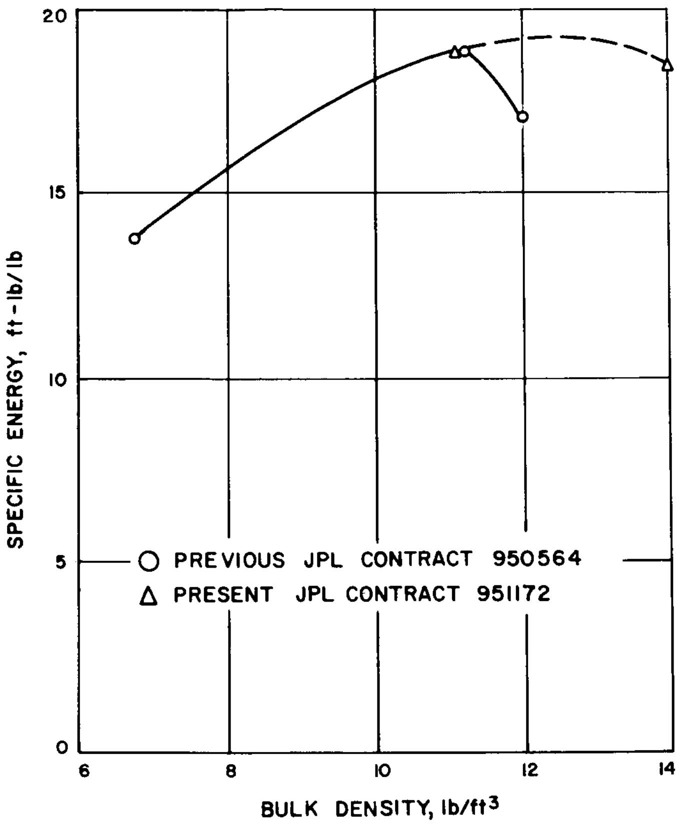


Fig. 1. Specific energy vs density for 3/16-in. cell phenolic honeycomb

SPACECRAFT STRUCTURAL VIBRATION TEST AND ANALYSIS

NASA Work Unit 186-68-01-03-55
JPL 384-68001-2-3530
W. H. Gayman

BJECTIVE

The objective of this work unit is to perform modal vibration surveys of the ırveyor Structural Test Model (S-9) and to derive from these surveys mathematical odels that can be used for comparison with analytically derived models of the ırveyor vehicle. The difference between the experimental and analytical results ill be critically evaluated. The evaluation will provide information for improving e mathematical model of Surveyor and will indicate potential areas of concern in ther testing or analysis of complex spacecraft structure.

EST PROGRAM

The experimental phase of this program is now under way. The S-9 vehicle d the adapter are in the Structural Test Laboratory. Initial testing indicated that cklash in the Antenna and Solar Panel Positioner gearboxes provided sufficient nlinearity to make the test results useless for the purposes intended. The gearbox ill be positively locked so that these nonlinearities are not present during the testing. ass moments of inertia and centers of gravity of critical components are being easured, and accelerometer mounting blocks are being prepared. When these preparations are completed, modal surveys will begin. Indications from previous work Surveyor are that many accelerometer stations will be required to delineate the odes with sufficient accuracy for a good orthogonality check. Plans are also under y to measure the structural transfer functions relevant to the closed-loop autopilot ability. This test will be conducted late in the program.

JBLICATIONS DURING FY 1966

None.

JBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

ELECTROMECHANICAL ACTUATOR DEVELOPMENT
NASA Work Unit 186-68-02-03-55
JPL 384-60401-2-3440
Gerald S. Perkins

BJECTIVE

The objective of this work unit is to advance the state of the art of the actuators ;ed in spacecraft control systems. It includes investigations of the actuation devices ; well as components required in these devices for attitude control, autopilots, and ·ticulation control systems.

ICROTHRUSTERS STUDY (MINIATURE ROCKET MOTOR)

The Solid Propellant Electric Thruster (SPET) engine consists of a propellant, propellant reservoir and feed arrangement, and a means for generating an electri- .l discharge across the propellant surface. The device can be considered as a form pulse plasma accelerator with a unique method of propellant feed. An electrical scharge occurring between appropriate electrodes caused the ablation of a self- plenishing film of propellant. A charged high-voltage capacitor is used as the .ergy source. By changing the energy, the total number and frequency of the dis- .arges, the amount and physical characteristics of the gas resulting from propellant ılation can be varied; thus, thrust and specific impulse can be varied. A propellant fed from the fuel reservoir to the firing chamber by capillary forces and held there surface tension ready for firing. Figure 1 is a typical firing circuit. Figures 2 .d 3 illustrate two experimental SPET thruster configurations; the thruster shown in g. 2 contains no accelerating electrodes.

:neral Electric Study Contract

A study contract has recently been completed with General Electric Missile d Space Division, Valley Forge, Penn. The purpose was to study the feasibility of 'ET for use as a spacecraft attitude control thruster.

lvantages of SPET

From the study results, the following advantages of SPET were ascertained:

1. No moving parts.
2. Mass flows can be precisely delivered:
   (a) At very low levels.
   (b) At levels varying over wide ranges.
   (c) With nearly unlimited start/restart capabilities.
3. Problems associated with extremely small throat areas are bypassed.

4. Problems associated with valves capable of metering and/or sealing small flows are avoided.

5. The dust contamination problem in production and assembly is eliminated.

6. Extremely small bits of impulse can be delivered and may be selectively and precisely varied.

7. Control is greatly simplified; solid-state variable frequency cir cuits with only digital command can be used.

8. The thruster is rugged and compact and promises greatly improved reliability and lifetime.

9. The thruster lends itself to natural growth to the high-power levels because of the unique features represented by the efficie delivery of mass flows of ionized gases at the most favorable locations and times, thus ensuring mass and energy efficiencie otherwise unobtainable.

Accomplishments

In the short time span of the SPET engine development, many significant accomplishments have been made:

1. 4.6 million firings of a SPET-A thruster operating at 1 joule firing once/sec.

2. Successful development of a vacuum analytical balance techniqu for the measurement of micro-pound impulses.

3. Thrust measured by direct reaction on pendulum and analytical balance.

4. First solution of time-dependent complete (one-dimensional) Navier Stokes Equations, and first application thereof to the SPET-D phenomenon.

5. High thrust/power (1 to 3 x 10^{-5} lb/w) demonstrated on SPET-

6. 1 x 10^{-4} to 1 x 10^{-6}-lb thrust demonstrated feasible on SPET- thruster at power levels of 5.0 to 0.5 w.

7. Specific impulse measured 800 to 4500 sec on SPET-A.

8. Impulses of 1.1 to 1.8 x 10^{-4} lb-sec/pulse measured on a sing shot basis, at energy inputs of 0.02 and 1.1 joules, and I_{sp} of and 37, respectively (SPET-D).

9. Power conditioning and logic developed and packaged.

10. Feed system of 5-yr fuel capacity developed.

11. Self-triggering mode demonstrated.

12. Supersonic arc-standing wave modes demonstrated (rails removed and comparable I_{sp} achieved).

13. Multistaging and series clustering demonstrated.

ollow-On Contract Objectives

A follow-on contract for the purpose of obtaining hardware for evaluation is ing negotiated. The objectives of this new contract are to:

1. Obtain two SPET-A assemblies for evaluation.

2. Demonstrate that a SPET engine can be designed and built to a specified set of performance requirements as follows:

   (a) Impulse bit. The engine shall produce an impulse bit per pulse between 10^{-5} and 10^{-4} lb-sec ±20%.

   (b) Repetition rate. A repetition rate of at least ten pulses/sec shall be achieved. The engine shall be capable of 1,000,000 pulses without requiring refueling or component replacement.

   (c) Power. The engine shall require no more than 10 to 30 w average power while being pulsed at its maximum pulse repetition rate.

   (d) Specific impulse. Specific impulse will not be specified; however, it is expected to be on the order of 2000 sec. The specific impulse of the thruster shall, however, be measured and reported.

   (e) Packaging. The engine and its power conditioning (firing circuit) shall be packaged in a magnetically shielded housing in a manner that will permit it to be placed on an impulse measuring balance. The total weight of the engine circuit assembly shall be commensurate with this method of impulse measurement. The package shall have no more than three low-voltage power leads (Fig. 4).

3. Submit a final report containing, but not limited to:

   (a) Description of the empirical and analytical design criteria defining SPET-A.

   (b) Description and pictures of the test equipment and its calibration procedures.

(c) Test results obtained in the development and final testing o the assemblies delivered to JPL.

(d) Conclusions.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. Perkins, G. S., "Solid Propellant Electrical Thruster," SPS 37-37, Vol. IV, p. 42, February 28, 1966.

Contractor Reports

1. Feasibility Assessment of a Solid Propellant Electric Thruster (SPET), No. 66SD4255, General Electric, Spacecraft Department, Valley Forge Space Technology Center, Philadelphia, Penn., March 15, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

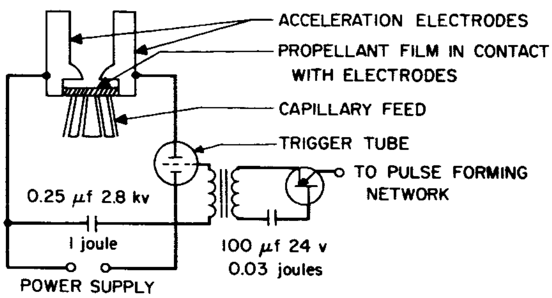


Fig. 1. Control system block diagram

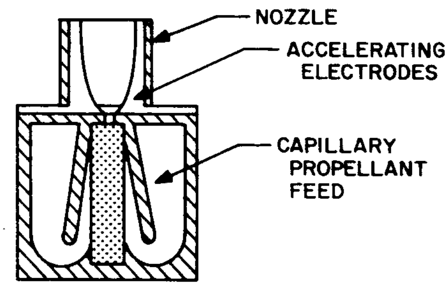


Fig. 3. Response to maximum input rate (0. 2 deg/sec)

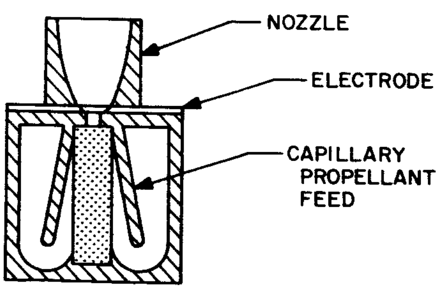


Fig. 2. Step response

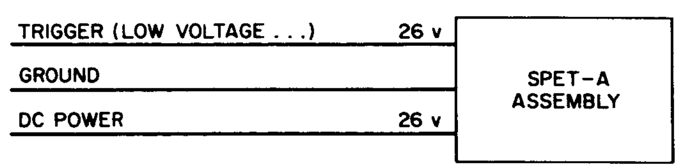


Fig. 4. Follow-on contract SPET engine package power leads

LUNAR AND PLANETARY HORIZON SCANNER
NASA Work Unit 186-68-02-04-55
JPL 384-60501-2-3440
J. M. McLauchlan

3JECTIVE

The objective of the Lunar and Planetary Horizon Scanner (LPHS) Program is ə development of a long-life infrared horizon sensor with no moving parts. This nsor will be useful on Voyager type missions for providing information regarding ə direction of the local vertical of a planet from an orbiting spacecraft. The velopment is being accomplished with the aid of an industrial contractor (Barnes ıgineering Co.) for design and fabrication; JPL is providing support in various sign areas, as well as detailed testing and evaluation.

ROGRESS

During the last reporting period, the contractor completed approximately 80% the detailed electronic, mechanical, and optical design necessary for fabrication an engineering model of the LPHS; he has also conducted preliminary breadboard- g and testing of some of the circuitry.

In addition, a contract modification was completed that provides for the con- ıctor to subcontract (1) for a special integrated circuit to be used in the breadboard nstructed during the design phase and (2) design and fabrication services of a ven- r specializing in electronic packaging. The final approval of this modification was layed because of questioning of the accuracy of the subcontracted efforts, but was bsequently approved in April 1966. The modification provides for completion of the sign phase in August and delivery of the final report and drawings in September, ich represents a slippage of approximately 3 mo in completing the design phase. e effect of this slippage on contract costs has been eliminated by reducing the el of effort at the contractor's during the first half of CY 1966.

Subsequent to the negotiation of the contract modification, further delays were urred at JPL and NASA in giving final approval to Barnes to subcontract with the egrated circuit vendor. This was caused by exceptions taken to the "New Tech- ogy" clause and other standard provisions by the subcontractor. This matter was bsequently resolved in June 1966, and approval was given to a final set of subcon- ct provisions. It is anticipated that this delay will affect the program schedule by proximately 1 mo.

The final circuit design provides for the use of redundancy in certain areas to ain greater reliability. A study by the contractor of the LPHS reliability indicates t the design objective of 90% probability of 3 yr of continuous operation can be ieved with the present design utilizing redundancy, but could not be achieved hout the redundancy.

TURE PLANS

A contract modification will be negotiated in the first quarter of FY 1967 for fabrication of a flight prototype model of a single-axis LPHS.

Delivery of the prototype unit to JPL will be in the third quarter of FY 1967 JPL will perform functional, closed-loop dynamic tests and qualification testing of this prototype unit during the third and fourth quarters of FY 1967.

If the testing indicates satisfactory performance of the LPHS, the development will be complete, unless a future program requirement arises for a more accurate device.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

IMAGE TUBE DEVELOPMENT
NASA Work Unit 186-68-02-05-55
JPL 384-60601-2-3440
D. S. Herman

BJECTIVE

The objective of this work unit is to improve the basic all-electrostatic Image issector (ID) that was used on Mariner IV; this work is begin conducted in onjunction with CBS Laboratories. Continued improvement of the tube charactertics are needed for high-performance star sensor and approach guidance planet ensor applications.

ASIC IMAGE DISSECTOR CONTRACT

The final report on the life test of two tubes on the basic contract (JPL 50054) was completed, and concluded that the tubes were capable of long-life operaon without major changes, although one of the tubes did change by an appreciable mount during the life test. However, this conclusion is supported by evidence from her tests including recent contact with Mariner IV, which indicated that the tube is ill operational in the Canopus Sensor.

HE WIDE-ANGLE, SHORT ELECTROSTATIC IMAGE DISSECTOR CONTRACT

A final report of the work performed on this contract has been completed. ne of the required tubes delivered to JPL was tested using the JPL test fixture; the ta was compared with that obtained by CBS using older test fixtures.

Tests indicate that the deflection drift (or hysteresis) has been eliminated by e incorporation of an improved Schlesinger deflection yoke.

The other areas of major concern were improvement in electron-optical esolution and distortion. Some improvement in resolution was obtained, but was ill short of the design goal, especially in the outer region of the photocathode. The eflection linearity of the tube was better than 1% in each axis taken individually; owever, there was a large amount of "pincushion" distortion for rectangular aperre tubes. A number of tubes built on the Sterilizable Electrostatic Image Dissecr, (SEID, NASA Work Unit 186-58-02-02-55) contract with small circular apertures d not seem to have the pincushion distortion.

PL-BUILT TEST FIXTURE

The test fixture for the ID tubes was completed and shipped to CBS for use in sting curved faceplate tubes of the new ID; this test fixture provides a better and ore automatic facility for testing the ID tubes.

UTURE ACTIVITIES

A new contract has recently been given to CBS for continued improvement of e ID tube. The work in the electron-optical area has been combined with the work a high-temperature photocathode (NASA Work Unit 186-58-02-02-55) in one conact. In addition to increased efficiency, the advantage is that the tubes built for

electron-optical experiments can also be used to test the high-temperature properti of the photocathode. A new deflectron will be designed to reduce deflection defocussing. Each tube fabricated will contain an electron-optical experiment in which electrode geometrical parameters will be systematically varied with the goal of improving electron-optical resolution. The tubes will be tested for their sterilizabl properties for the high-temperature photocathode program. In addition, a 10,000-h life test on six tubes will be performed. Two sterilized tubes will be maintained at 165°F and four, two of which have been sterilized, will be maintained at room ambient under specified operating conditions.

PUBLICATIONS DURING FY 1966

Contractor Reports

1. Karpinski, J. Z., "Final Report, One Year Life Test of 1-1/2 Inch Image Dissector," JPL Contract 950054, CBS Laboratories, December 13, 1965.

2. Karpinski, J. Z., "Final Report, Short Wide Angle, 1-1/2 Inch Electrostatic Image Dissector with Parallel Plate Resistive Strip Electronic Multiplier," JPL Contract 959508, CBS Laboratories, December 1, 1965.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

FLIGHT COMPUTERS AND SEQUENCERS
NASA Work Unit 186-68-02-08-55
JPL 384-63701-2-3410
G. R. Hansen, Jr.

BJECTIVE

The objective of this work unit is to develop and evaluate logical organizations, ircuits, and components for advanced spacecraft Central Computer and Sequencer C&S) subsystems. The CC&S requirements considered include those for the space-raft bus as well as orbiter or lander capsules. The longer range objectives are ncerned with defining and instituting tasks leading to the development of CC&S sub-ystems for complex planetary missions requiring substantial increases in operating fe in more severe environments.

JPPORT OF MARINER MARS 1969

Since February, the design analysis, component specifications, and electrical hematics for the Mariner Mars 1969 CC&S have been completed. Most of the anal-is techniques and application criteria developed for integrated circuitry under rlier efforts under this work unit, as well as the personnel who generated these chniques and criteria, played a major role in establishing the design.

Efforts have been instituted recently to improve the design efficiency of the ariner Mars 1969 CC&S by introducing a new series of integrated circuitry. The forts under this work unit are aiding in the establishment of application criteria and vice specifications for the new integrated circuits. The ultimate rewards will be a wer reduction of up to 50% with a concomittant 5 to 10% weight and volume increase. e power reduction will be a significant contribution to the overall spacecraft design, ich presently is faced with severe problems because of limitations in available wer.

The direct project support effort is expected to end in the first quarter of Y 1967.

GICAL ORGANIZATION

The expected accomplishments in this period on tasks such as the completion the Inhibit Core Logic mechanization of the two-memory sequencer and studies of dundancy schemes were not realized because of the support to the Mariner Mars 69 Project. These two tasks will be resumed in FY 1967.

RCUITS

All testing of hybrid and magnetic circuits has been held in abeyance for this riod; however, the equipment necessary for the fabrication of chip component brid circuits has been received. This equipment is presently being installed, and rication of sense amplifier-transfer circuits will be started during the next porting period.

COMPONENTS

The second contract for welding of magnet wire negotiated in the second quarter of FY 1966 was cancelled after completion of the first phase. This contrac called for a feasibility demonstration using a thermocompression method, but the effort was judged unsuccessful before the contract was scheduled to end.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

ADVANCED SCAN PLATFORM

NASA Work Unit 186-68-02-09-55
JPL 384-61901-2-3440

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T. Kerner

BJECTIVE

The objective of this work unit is to demonstrate the feasibility of a Scan latform System optimized to accommodate a multiplicity of science requirements. he optimization will be effected in terms of flexibility, pointing accuracy, velocity tter, transient response, and structural characteristics.

In consultation with the Space Sciences Division, certain specific performance bals have been established; the most important are:

1. Maximum time to acquire (inside deadband) from maximum angular error (60 deg) = 60 sec.

2. Accept input rates up to 0.2 deg/sec (3.5 mrad/sec).

3. Platform jitter in the order of 100 μrad/sec.

4. Maximum overshoot of platform from deadband should be less than θ_{SLEW} (4 deg).

YSTEM MECHANIZATION

Preliminary study made of a stepper motor actuated system showed that the w platform jitter requirement (100 μrad/sec) was only marginally satisfied. Invesgation was concentrated around an induction motor system. Figure 1 shows the sic block diagram of the control system using an induction motor. The horizon anner used was described in the last report covering this effort. Its output for ch scan period consists of pulses, the sum of which is proportional to the misignment between the local vertical of the planet viewed and the optical axis of the rizon scanner. To ensure finite loop gain of the system at zero crossover, a ite deadband is essential. The three-pulse detector shown in Fig. 1 has the aracteristic of no output for two pulses or less, and a logical 1 output for three lses or more. This implements a 1- to 2-deg deadband. The nine-pulse detector s similar characteristics. The system as shown operates in two modes. When e error exceeds nine pulses, which corresponds to a minimum of a 4-deg error, the lay K_1 is energized imposing θ_{SLEW}, the slewing rate, directly on the induction otor which drives the platform structure. For an error between 2 and 4 deg, relay is de-energized and the three-pulse detector output is fed to an RC filter through gain K, which in turn drives the motor, so that $\dot{\theta}_M$ (motor rate) is now equal to K. he angular error is reduced at this rate, until it is within the deadband (between 1 d 2 deg), at which time the three-pulse detector output is zero, and the RC network gins to discharge, decreasing platform rate. Note that the pulse detectors are echanized as latched types (using flip-flops) that can change state only at clock lse intervals, corresponding to the sensor sweep. The detectors thus provide the nction of a sample-hold circuit.

SYSTEM RESPONSE

For a step input, the system enters a limit cycle from edge-to-edge of the deadband, with exponentially decreasing rate, until the capacitor voltage is less tha the motor threshold voltage, at which time the system comes to rest inside the deac band. This condition represents a hypothetical case, however, since the scan platform is always subjected to a nonzero rate input.

For a ramp (or any nonzero rate) input, after the initial overshoot, the system enters a one-sided limit cycle against the leading edge of the deadband. This limit cycle, theoretically, exponentially decreases in amplitude until an infinitesim oscillation results. Because of the platform dynamics and the sampling nature of tl system, however, a minimum limit cycle amplitude results.

Using the IBM 1620 computer, and a Digital-Analog Simulator Program (DIANA), the control system was simulated.

The step response of the system is shown in Fig. 2. The plot represents th system position error vs time, with the initial position equal to $+\theta_{SLEW}$ (70 mrad) and initial platform rate equal to $\dot{\theta}_{SLEW}$ (21 mrad/sec). For the two cases, the maximum overshoots are nearly equal at approximately 36 mrad.

Since a step input represents the maximum overshoot, these plots indicate that performance requirement (4) is satisfied, with a 34-mrad safety margin. Afte the initial overshoot, the platform coasts into the deadband with an exponentially decreasing rate.

Figure 3 shows the system response to the maximum input rate (0.2 deg/se This case was run with a ±2-deg deadband. The steady-state limit cycle amplitude: had an RMS value of 119 mrad. The RMS rate error (defined as the difference between the platform and input rates) was 105 mrad/sec. This rate error could be considered as the platform jitter; however, it should be pointed out that this limit cycling represents a smooth, slowly varying (approximately 0.1 Hz) platform motion; thus, only a small component of this motion may propagate to the platform instruments as jitter.

CONCLUSIONS

Comparing the simulation results discussed above with the performance goa listed in the objective, it seems that this type of system can meet the scan platforn requirements satisfactorily. To verify the simulation results and determine the effects of hardware limitations, it is necessary to mechanize the system as a brea board and subject it to the input conditions mentioned.

FUTURE EFFORT

Components have been purchased to construct breadboard test units for the induction and stepper motor systems. The initial breadboards will simulate the pl form and actuator dynamics with torsion rods and inertia wheels. The horizon scanner will be simulated with precision potentiometer position sensors and sampl circuits until the actual scanner becomes available.

Eventually, a complete dynamic simulation will be performed with a scanning latform, horizon scanner, and simulated planet characteristics.

UBLICATIONS DURING FY 1966

PL SPS Contributions

. Kerner, T., "Horizon Scan Platform System," SPS 37-37, Vol. IV, pp. 47-51, February 28, 1966.

. Mankovitz, R., "Horizon Scan Platform Control System," SPS 37-39, Vol. IV, June 30, 1966.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD.

None.

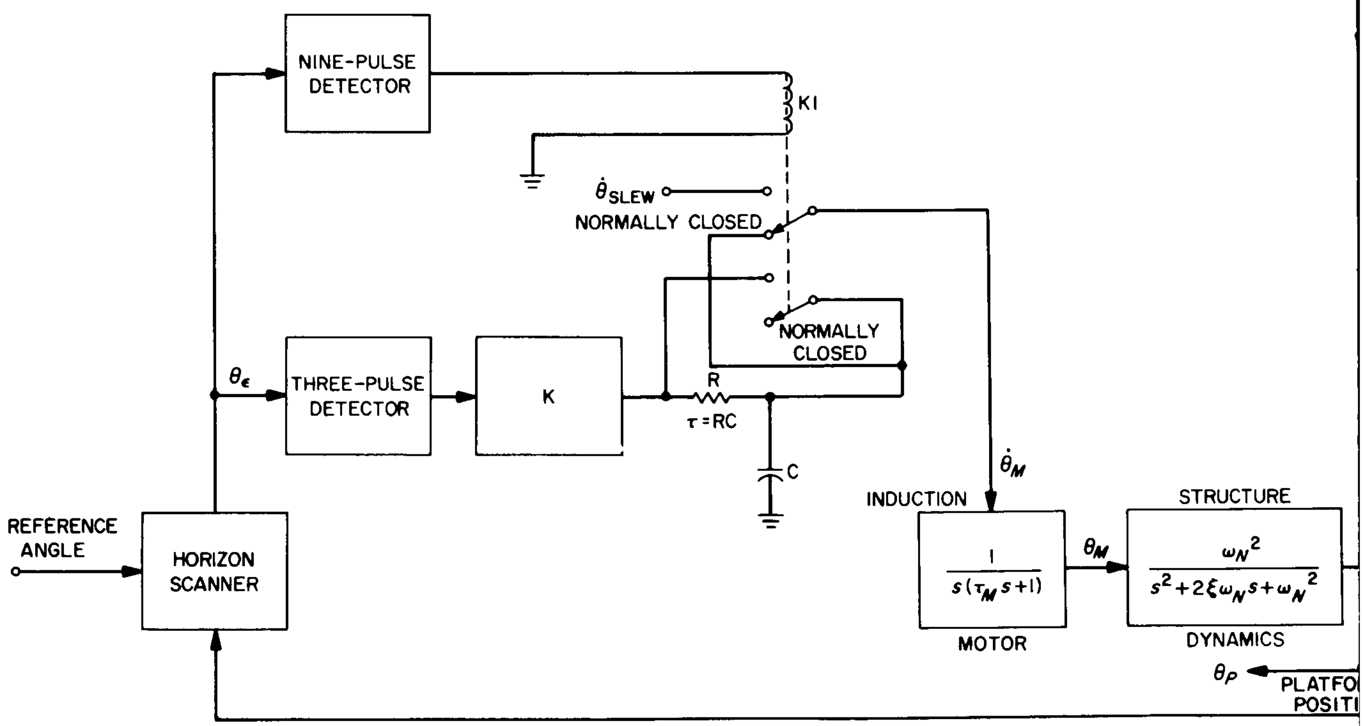

Fig. 1. Control system block diagram

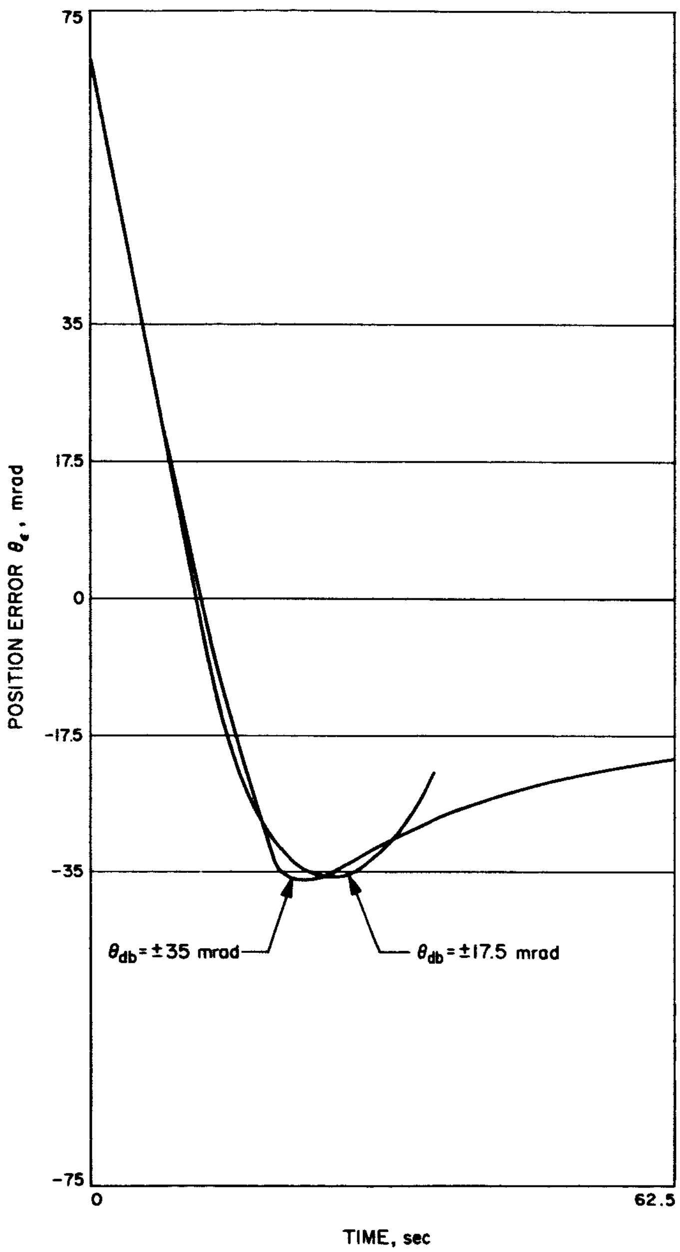

Fig. 2. Step response

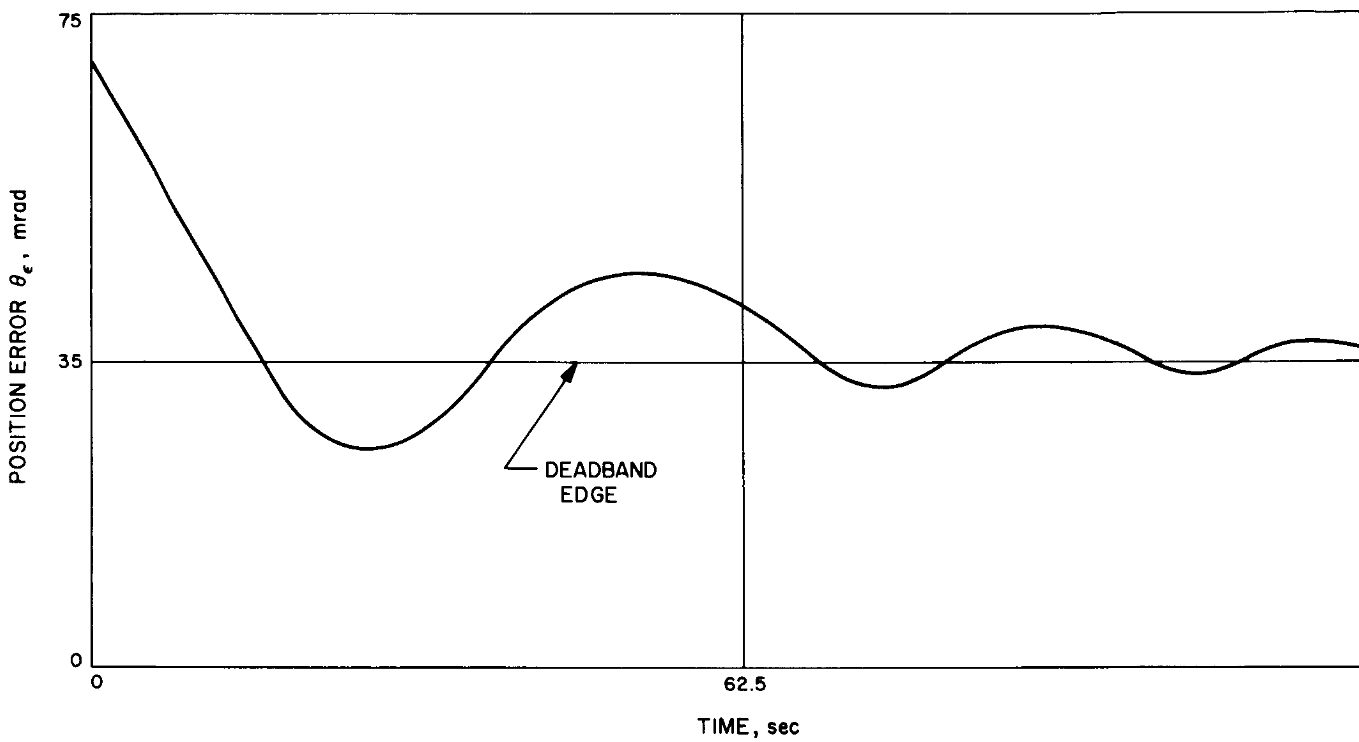

Fig. 3. Response to maximum input rate (0.2 deg/sec)

SPACECRAFT GUIDANCE RADARS

NASA Work Unit 186-68-02-14-55
JPL 384-61001-2-3360

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BJECTIVE

The objectives of this work unit are to develop a well-founded radar apability and to develop radar prototypes for use on future spacecraft. The immedi-te objective is to learn, analyze, and classify guidance radar techniques for use on oard spacecraft as altimeters and velocity sensors.

NALYSIS OF SURVEYOR RADAR AND DOPPLER VELOCITY SENSOR

The objectives of this task are to: (1) obtain a complete and thorough analy-is of the Radar and Doppler Velocity Sensor (RADVS) in order to understand the peration, assets, and liabilities of the system in its current mechanization, and 2) create theoretical ground work for a guidance radar more generally useful than ne designed solely for lunar landings. The analysis of the system is divided into our main sections as follows.

nalysis of Radar Return Signal

Work continued on this analysis by making modifications to ease computations. he return signal power equation is also used in the calculation of the spectral shape f the return signal. A previous equation contained a two-dimensional integral over e illuminated surface. By noting that, for a moving antenna, lines of constant dop-ler frequency (isodops) trace out ellipses on the surface, considerable simplifica-on can be accomplished by integrating along the isodops. Analysis and documenta-on has been completed.

nalysis of RADVS Receiver Transfer Function

This analysis treats the system as linear from the radar front end through the ascade of filters to the frequency discriminator input. Successful completion and ocumentation of this analysis was accomplished during this reporting period.

uasi-Static AFC Loop Analysis

During this reporting period, an expression for the output mean value of the ADVS frequency discriminators was derived and computed for various input signal--noise ratios. The results showed a significant change in loop gain factor with gnal-to-noise, which affects the accuracy of the RADVS output signals. Since only e mean value was analyzed, this work is not considered complete.

valuation of RADVS Performance Margins

Performance margins for acquisition and tracking were made prior to the urveyor flight. Predictions show that, for worst-case situations, the RADVS may

be restricted to a 25-deg entry angle rather than the specified 45-deg design goal.

ASYMPTOTIC FORM OF AN OPTIMUM RECEIVER FOR EXTRACTING INFORMATION FROM GAUSSIAN SIGNALS OBSERVED IN WHITE GAUSSIAN NOISE

In many radar systems, the signal observed at the input of the radar receiv is the sum of a gaussian information-bearing signal and white gaussian noise. The gaussian information-bearing signal is generated during the reflection of a signal from some surface. The white gaussian noise is added by the receiving system. T objective of this analysis is to define the receiver that should be used to extract inf mation from such signals.

The function of the receiver is to evaluate an information-dependent measur on which we can base a decision as to what information was carried by the gaussian process observed in white gaussian noise at the receiver input. The optimum receiver used a posteriori probability for this measure. This analysis obtains a particularly simple form for this a posteriori probability.

DETERMINATION OF GUIDANCE RADAR FUNCTIONAL REQUIREMENTS AND NEEDS

The objective of this task is to determine if the future spacecraft needs and functional requirements are the same as the RADVS or whether entirely new conce are necessary.

In meeting the objectives of this task, a survey was made of current techniques, system designs, and hardware capabilities. Trips were taken to:

1. Manned Spacecraft Center, Houston.
2. Marshall Space Flight Center, Huntsville.
3. Texas Instruments, Inc. (Apparatus), Dallas.
4. Westinghouse, Baltimore.
5. Sperry Gyroscope Co.
6. General Precision, Inc.

Additional contacts have been made with other NASA centers by surveying the NAS "Program Digest Flash Index."

The most immediate need for a guidance radar has been determined to be t for the Voyager Project to land a capsule on Mars. A team was formed with repr sentatives from the various technical disciplines to study a preliminary capsule design incorporating the guidance radar concept.

The radar effort made contributions on the following topics:

1. Factors important in designing a radar descent system.
2. Noise model of a radar including dc offset errors as well as random noise.
3. Plasma blackout during atmospheric entry.
4. Comments on acquisition and tracking of velocity and range rates.
5. RF interface problems with the aeroshell.
6. Measurement capabilities of pulse, continuous wave, frequency-modulation/continuous wave systems.
7. One possible configuration including weight, volume, and power consumption.
8. Areas for additional study.

ne most significant development of this study in relation to the Spacecraft Guidance adar work unit is the identification of the extremely difficult interface with the cap-ule aeroshell.

VESTIGATION OF PULSE RADARS FOR SPACECRAFT GUIDANCE

The objective of this task is to investigate a radar mechanization for soft nding on a planet other than the current Ryan RADVS System to determine whether has greater potential in application and accuracy and fewer problems.

This task will be accomplished through two different routes: (1) to assume entical requirements as those of the RADVS System and investigate mechanizations ilizing pulse techniques rather than continuous wave techniques, and (2) to investi-te alternate mechanizations using pulse techniques to implement the functional quirements for a landing on Mars.

The literature survey was continued; however, the main effort was concen-ated in studying the lobing techniques associated with pulse radars. For the conical an or sequential lobing technique, two areas were investigated. Of particular terest is the case where the conical scan period is large in comparison to pulse ngth. It was felt that, in addition to range information, one could also determine titude information by use of such conical scan methods. Unfortunately, in order to tain this information, one must analyze completely a nonlinear estimation problem r a nonstationary, narrow-band, non-white, gaussian random process.

An initial look has been given to the case where pulse length is short with spect to the conical scan period. This, in effect, represents a multilobing sys-m and does appear to have definite value in terminal guidance systems. Further nsideration will be given to this method in order to determine if any advantages ist over other lobing techniques.

The International Symposium on Information Theory, held at UCLA from January 31 to February 2, was attended in order to keep abreast of the latest devel ments in the areas of modulation theory, detection theory, and signal design.

GENERAL GUIDANCE RADAR DEVELOPMENT

As the functional requirements and needs are more closely defined, specifi mechanizations will be studied. In support of this, contract support for people oriented in hardware has been approved for the amount of $35,000. The vendor wi be selected during the first quarter of FY 1967.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. Koerner, M. A., "Asymptotic Form of an Optimum Receiver for Extracting Information from Gaussian Signals Observed in White Gaussian Noise," SPS 3' 38, Vol. IV, pp. 206-210, April 30, 1966.

2. Horttor, R. L., "RADVS Frequency Discriminator Analysis," SPS 37-38, Vol. IV, pp. 212-217, April 30, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

PLANET TRACKER
NASA Work Unit 186-68-02-15-55
JPL 384-64401-2-3440
D. G. Carpenter

3JECTIVE

The objective of this work unit is to develop a planet sensor capable of directing ientific instruments toward the center of planet visible light. This sensor would so be applicable for antenna pointing.

The planet sensor will be capable of operating from light sources as dim as t-c and as bright as the Sun (12, 600 ft-c at Earth) without moving parts or pro- :tive Sun shutter.

ESENT ACTIVITIES

During the last reporting period, functional testing was completed on the gineering evaluation model planet sensor and a final report was written.

Table 1 presents the operating, mechanical, and electrical characteristics of planet sensor in its present configuration. With the present mechanical param- rs, the planet sensor will track and null, on the "center of illumination," a planet otending a total angular diameter of from 5 to 60 deg. By shortening the lever arm l modifying the electronics to increase amplifier gain, a planet as large as 100 deg gular diameter can be tracked with acceptable operating characteristics. The net tracker is simple in design and operation, uses no moving parts and uses nmon, highly reliable electronic components. The sensor is small in size, light- ight, and has a low power consumption. Possible applications include pointing of a ence platform on approach to or orbiting of a planet, pointing of an antenna toward Earth, or other similar tasks where the limited accuracies of a center-of-illumi- ion-type planet tracker are acceptable.

TURE ACTIVITIES

Work is completed on the chosen design. The work unit is terminated.

BLICATIONS DURING FY 1966

L SPS Contributions

Carpenter, D. G., "Wide Angle Planet Tracker," SPS 37-39, Vol. IV, June 30, 1966.

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

Table 1. Wide-angle planet sensor characteristics

I.	Operational characteristics		
	A.	Basic operation	Center-of-illumination sensor
	B.	Detectors	Cadmium sulfide photoconductors (CLAIREX-7051)
	C.	Operating range	5 to 100 deg (angular diameter)
	D.	Field of view	
		1. Total tracker (γ)	135 deg
		2. Linear (α)	45 deg
		3. Acquisition	50 deg
	E.	Sensitivity	Operatc from 1.0 to 720 ft-c
	F.	Sun protection	Able to withstand full solar illuminatio with no Sun shutter
II.	Unit characteristics		
	A.	Total power dissipation	≤0.5 w
	B.	Size	32 in.^{3} (4.0 x 2.8 x 2.8 in.)
	C.	Weight	>0.85 lb
	D.	Lever arm length	0.175 in.
	E.	Shadowing	Knife edge half shadows detectors at n
III.	Output characteristics		
	A.	Error signal	Two axis (roll and hinge)
	B.	Scale factor	
		1. 5-deg planet	1.675 v/deg
		2. 20-deg planet	1.25 v/deg
		3. 40-deg planet	0.82 v/deg
		4. 60-deg planet	0.355 v/deg
		5. 100-deg planet	0.115 v/deg
	C.	Acquisition signal	Not acquired = ≤0.5 v; acquired = ≥8.C
	D.	Intensity signal	1.0 to 2.6 v (for inputs of 1.2 to 720 ft
	E.	Time constant	≤0.5 sec at 1.0-ft-c illumination

OPTICAL SENSOR TECHNIQUES
NASA Work Unit 186-68-02-19-55
JPL 384-64601-2-3440

D. G. Carpenter
E. S. Davis
D. S. Herman
L. Schmidt

)BJECTIVE

The objective of this work unit is to advance the state of the art in the area of ens design, electron-optical systems, photoconductors, and infrared detectors.

ENS DESIGN

The objective of this work unit is to further develop an Automatic Lens Design 'rogram into a practical design tool, flexible enough to handle most optical designs, et one that is not unwieldy to use for simple optical systems.

ens Design Seminar

A Lens Design Seminar was presented at JPL February 8 through 10 for personnel from all NASA centers. The seminar covered the theory and operation of the utomatic Lens Design Program and included sample problems as well as problem xercises completed by the seminar participants. Approximately 10 persons attended epresenting two sections of the Manned Spacecraft Center, two sections of the Flight esearch Center, and two other sections of the Jet Propulsion Laboratory. Since the eminar, both sections from the Flight Research Center and one section from the lanned Spacecraft Center have utilized the program.

ens Design Report

The Lens Design Report was reproduced in rough draft form to meet the needs the seminar. Approximately 30 copies have been distributed to seminar particants and other interested parties. This report has not been officially published ecause of other tasks of higher priority.

ar Tracker Lens Design

The Star Tracker Lens Design previously reported was discontinued because Mariner Mars 1967 requirements. One of these requirements was the design of a ns for the Canopus tracker. The major difference was the requirement that the lens provide a flat image plane instead of a curved one to match the inside curvare of the Image Dissector. The Lens Design Program proved to be indispensable completing this design in a short time (approximately 6 wk). This lens has just een fabricated and, although not thoroughly tested, seems to perform as intended.

It is anticipated that the earlier Star Tracker Lens Design will be resumed in der to provide a Star Tracker Lens Design for the Mariner Mars 1969 mission.

Lens Design Program Changes

The program has been changed to allow a minimum spacing between surface to be specified for each distance location. Previously only maximum values could assigned.

It is expected that rewriting of the program into FORTRAN language will sta within 2 mo. During this phase, the least-squares minimization technique will als be evaluated. It should be practical to modify the minimization technique to reduce the computer time required for convergence.

ELECTRON-OPTICAL DESIGN PROGRAM

The objective of this activity is to develop a digital computer program to be used in the analysis and design of electron-optical systems. This effort is in supp of the Wide-Angle Image Dissector Program where improvement of off-axis electr optical resolution is needed.

Progress

A method for determining the electron trajectory in an electrostatic electro optical system consisting of a number of lenses has been suggested by E. Keberle and W. Silslic of the JPL Scientific Programming Section. This suggestion is pres ently being implemented into a computer program for determining the electron trajectory.

Future Activity

During the next reporting period, it is hoped that the computer program fo determining the electron trajectory will be completed. It will then be used to dete mine the electron trajectories in the electron-optical system which makes up the front end of the electrostatic Image Dissector and other electron-optic systems. I addition, if the program is successful, it will then be possible to use it as the basi for an electron-optic program similar to the light-optic design program.

PHOTOCONDUCTOR PERFORMANCE IMPROVEMENT

The primary objectives of the work unit are to: (1) establish pertinent and reasonable requirements for cadmium sulfide photoconductors for spacecraft use and (2) obtain photoconductors that meet these necessary requirements.

Vacuum-Deposited Photodetectors

The Autonetics contract for the fabrication and testing of vacuum-deposited photoconductors is complete. The final report gives data indicating that the Autonetics vacuum-deposited cells are not significantly superior to sintered type cells. However, they are sterilizable, while the sintered cells are not.

Future Activity

Because of funding and priorities of other tasks, this work unit has been su pended until FY 1968.

However, work is under way in Section 345 (NASA Work Unit 129-02-05-01-55) n vacuum-deposited cadmium sulfide materials. It is hoped that much will be earned from that project to aid in meeting the objective of this work unit.

HERMOELECTRIC INFRARED DETECTOR RESEARCH

The objective of this work is to improve the thin-film thermoelectric detector. his type of detector is used in the electronically scanned Lunar and Planetary orizon Scanner (LPHS, NASA Work Unit 186-68-02-04-55).

hermoelectric Detector Research

This work has been conducted by the Barnes Engineering Company on a level--effort basis. The major effort during the past 6 mo was expended in the materials rea. Thin-film thermocouples and thermopiles were fabricated using bismuth/ ntimony (Bi/Sb), bismuth/tellurium (Bi/Te), and n and p type Bi_2Te_3 compounds. ne condition necessary for near bulk electrical resistance has also been obtained r the Bi/Sb and Bi/Te combinations, but not for the Bi_2Te_3 compounds, because eproducibility and bulk conditions for thin-film detectors are difficult to achieve in e compounds. In addition, it seems that the Bi/Sb combination will be capable of ithstanding Voyager-type sterilization requirements. However, with the Bi/Sb and i/Te materials evaporated under the best evaporation conditions and the 1/4-mil ylar substrate, only small improvement in detector responsivity was achieved.

uture Activity

For the remaining contract time, the effort will concentrate on reducing the eat losses from the hot junction of the detector, especially through the substrate, hich should increase responsivity. Thin substrates, such as a new material manu-ctured by Union Carbide called Parylene, will be tried. Parylene is a thin-film electric formed by evaporation. A 2-μ-thick substrate will be attempted.

GNAL PROCESSING

This work is directed toward improving the functional performance and sim-icity of star sensors.

tivities

No work has been performed on this task during the past 6 mo because the gnizant engineer has been involved on Mariner Mars 1967 activities.

anned Activities

Since one of these systems will be selected for Voyager, this task will be mpleted in the next 6 mo. The signal processing techniques studied will be docu-ented and reported in the JPL SPS.

PUBLICATIONS DURING FY 1966

None.

PULBICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

GUIDANCE AND CONTROL SUBSYSTEMS: INTEGRATION FOR FUTURE MISSIONS

NASA Work Unit 186-68-02-21-55
JPL 384-65201-1-3430

W. G. Breckenridge

BJECTIVE

The long-range objectives of this work unit are to study the interactions among ıidance, attitude control, computing and sequencing, and power subsystems for nar and planetary spacecraft; and to utilize the information obtained for the devel- pment of coordinated, compatible guidance and control subsystem configurations. nother objective of this work unit is to develop analytical techniques with common pplication among several subsystem elements, such as reliability assessment and pportionment techniques.

Emphasis in the current fiscal year has been on the design of an approach ıidance system for planetary spacecraft. Other work planned for FY 1966 has not een performed because of delays in bringing staffing to the allotted manpower level. hese delays are the result of recruiting difficulties.

The efforts in this work unit are a complement to, and are coordinated with, e efforts in NASA Work Unit 125-17-05-01-55, "Guidance Studies for Future Missions."

PPROACH GUIDANCE

Approach guidance occurs during the last few days before encounter (closest pproach) with the target planet. During this time, when the spacecraft is within a w million kilometers of the target planet, spacecraft-based optical guidance meas- ements of the direction to the target planet with reference to the Sun and other ars are feasible. These measurements provide information from a different urce than Earth-based radio guidance measurements, and the errors affecting the o measurement types arise from different sources. Hence, the optical guidance easurements enable increased accuracy and reliability of flight-path (orbit) deter- ination, which is an essential step in the guidance process. These measurements ay be telemetered to Earth and processed in conjunction with those from Earth- sed radio tracking to improve the accuracy, timeliness, and reliability of approach bit determination over that possible with the radio measurements alone. The tical measurements also may be processed in a spacecraft-based computer to complish the orbit determination and maneuver computation required for a self- ntained spacecraft guidance system. Optical guidance measurements are required r accurate flight-path control in missions to comets, asteroids, and planets with latively poorly known ephemerides. With the addition of on-board computing capa- lity to that of optical measurement, a self-contained guidance system is possible the spacecraft. Such a system can serve as a backup to Earth-based processing the guidance measurements, and can serve as the primary system for missions ıere communication with Earth, for guidance purposes, is inconvenient (e.g., issions to planets beyond Jupiter, where round-trip communication times are veral hours long).

In the last half of FY 1966, the major effort in the area of approach guidanc has been the preparation of a proposal, "Technology Development and Flight Feasi bility Demonstration: Spacecraft-Based Optical Approach Guidance Measurements which was presented to the NASA Offices of Advanced Research and Technology an Space Science and Applications on May 6, 1966. The proposal concerns the demon stration during the Mariner Mars 1969 mission of the feasibility of the approach gu ance concept. This demonstration will be performed on an "off-line" experimenta basis only; no approach maneuvers will be performed. The spacecraft will carry optical planet approach tracker; the outputs of this tracker and other spacecraft se sors will be telemetered to the Earth. These spacecraft-based optical guidance measurements will be processed in conjunction with Earth-based radio measurem to perform the orbit determination and maneuver computations required by approa guidance. These operations will be done on a real-time basis as part of the missi operations to demonstrate the feasibility of ground-based approach guidance comp tations. The increased orbit-determination accuracy available from post-encount radio tracking, and estimates of propulsion system performance derived from mic course maneuver performance analysis will be used to evaluate the adequacy of th pre-encounter approach guidance computations. The measurements obtained duri the approach phase also will be processed by ground computer simulations of a spacecraft-based computer to demonstrate the feasibility and performance potenti of a self-contained on-board approach guidance system. The functional requirem and software for the flight feasibility demonstration of approach guidance are base on previous work done under this work unit. The planet tracker hardware develop ment is based on the efforts of JPL Section 344 (NASA Work Unit 125-17-02-01-55 The effort on the flight feasibility demonstration will continue through FY 1970 to develop the system, perform the flight test, and analyze the results of the flight t

In view of the increased emphasis on approach guidance for future mission the procurement of an approach guidance analytical study has been initiated. This study is applicable to self-contained on-board approach guidance, as well as to th hybrid spacecraft/Earth-based concept being demonstrated during the Mariner M 1969 mission. The initial phase of this procurement is to perform work that coul not be performed in-house during FY 1966 as a result of delays in bringing in-hou staffing to its planned level. The funds to be used for this phase of the procurem are those that otherwise would have been used to defray in-house labor costs. Si lar funds from NASA Work Unit 125-17-05-01-55, "Guidance Studies for Future Missions," have also been directed to this procurement. Phase I of the study wil provide assistance in the documentation, mathematical modeling, and computer simulation of the current approach guidance concept. Later phases will accompli performance evaluation of this concept and alternate concepts to be developed.

A preliminary computer simulation of the spacecraft-based optical measu ment system has been developed under this work unit. This simulation is to be u for evaluation of the mathematical model of sensor noise characteristics used in p vious analytical studies. Of particular interest are the effects on the orbit estimat process of spacecraft attitude-control limit cycles and digital telemetry quantizat

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

DEVELOPMENT OF ACTUATOR PROCESSES
AND MEASURING TECHNIQUES
NASA Work Unit 186-68-02-22-55
JPL 384-64701-2-3440
E. F. Koch

BJECTIVE

The objective of this work unit is to determine by both analytical and ;perimental means the characteristics of spacecraft torquer mechanisms. To ·fine minimum impulse, response time, thrust levels of pneumatic thrusters, and ak rate of complex spacecraft systems are some of the contemplated tasks associ-ed with this work unit.

ROGRESS

The present effort is divided into two subtasks:

1. Thruster/nozzle experimental determination and analysis.

2. Design of a helium leak measurement technique compatible with large, complex assemblies.

ıruster Experimental Analysis

Utilizing in-house manpower and equipment, tests were initiated to determine ɜ thrust profile of attitude control thrusters that were used in the Ranger Project. ıe purpose was to devise the test technique for determination of thrusters to be ed on future programs. Great difficulty was encountered in instrumentation, so ɜ effort was redirected to determine the parameters of greatest need and least ficulty first. Present experiments are directed toward thrust and impulse deter-nation. Once the instrumentation is completed for these parameters, thrust ofile determination will be attempted.

Experiments were run with a low-frequency cantilever beam correlating thin 1.3% on impulse and within 3.2% on thrust level with analytical results. A ger, more sensitive, low-frequency, cantilever beam using strain gages is pres-tly being fabricated.

g Leak Test Technique

Since the last reporting period, the decision has been made to finalize the ;hnique as well as to determine some of the accuracy determining parameters by ntract. Subsequent to this decision, a work statement has been written and leased to nine potential contractors in an RFP. Out of the list of possible vendors, ly one, General Electric Company of Schenectady, New York, has proposed. The oposal is well above the available funds. However, negotiation is yet to be con-cted and may bring the cost in line with available funds.

The contract is intended to determine leakage characteristics, correlation ween helium and nitrogen leakage through the same path, optimum bag material, l a design guide outlining the procedure and describing how to reduce data to aningful engineering measurements.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. Randall, J. C., "Attitude Control Thrust-Nozzle Measuring Techniques, SPS 37-39, Vol. IV, pp. 40-42, June 30, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

ADVANCED SPACECRAFT DIGITAL MAGNETIC TAPE RECORDER DEVELOPMENT

NASA Work Unit 186-68-03-01-55
JPL 384-60901-2-3340

E. Bahm
W. Clement
J. Hoffman

OBJECTIVE

The objective of this work unit is to develop a standardized family of digital magnetic tape recorders, which is lighter, less power-consuming, and more reliable than those presently available, with storage capacities of 10^6 to 10^{10} bits for use in future NASA spacecraft. The effort emphasizes the reliable long-life operation that will be required by the Voyager class of planetary missions.

MAGNETIC TAPE STUDY PROGRAM - W. Clement

This is a continuing program of evaluation and study of the electrical and mechanical characteristics of magnetic tape. The purposes are (1) to solve specific problems, and (2) to keep abreast of new developments in the industry.

General Background

Magnetic tape is the one critical element in a tape data storage system. Little can be done with regard to optimization of characteristics for a particular application because tape production technology is extremely complex and costly, and spacecraft applications of tape constitute a negligible profit motive for the manufacturer. It, therefore, becomes important for JPL to conduct a tape evaluation program in considerable depth so that characteristics of other elements (heads, transports, etc.), over which control can be exercised, may be optimally matched to the tape. It is also, of course, important to be able to consider the tradeoffs in performance characteristics between the different types and brands of tape; this capability also results from such an evaluation program.

Two specific problems are considered to exist with regard to the Voyager class of mission: (1) layer-to-layer adhesion of the spooled-up tape pack during long dormant periods, which could result in catastrophic failure of the tape transport, and (2) tape wear, which could result in appreciable system degradation before completion of the mission.

Status

A test device has been constructed by the Applied Magnetics Corporation (AMC) under the joint cognizance of GSFC and JPL personnel (GSFC funded) in which the friction characteristics of magnetic tape can be evaluated under well controlled conditions. Two general categories of data are expected to evolve from the use of this device: (1) a measure of the tendency of tape to adhere to metal surfaces, such as heads, guides, etc., and (2) a measure of the tendency of tape to adhere to Mylar film, e.g., layer-to-layer adhesion. Some tests have already been conducted and more are planned. Evidence has already been obtained that all brands of magnetic

tape can be improved by a heat-curing process (improved in the sense that "stickiness" at elevated temperature is reduced).

A small test fixture for measuring directly the layer-to-layer adhesion in spools of tape is being developed as an in-house project. This fixture will allow several spools of tape to be exposed simultaneously to any combination of temperature, humidity, and time conditions after which the layer-to-layer adhesion of each tape sample can be measured.

Eight different samples of Mylar-backed tape from four manufacturers were evaluated for the presence of halogens (the presence of halogen compounds in magnetic tape binder systems is considered a detrimental factor in sealed tape recorders for spacecraft applications). In each test in which the presence of halogen compounds was established, corrosiveness to copper and zinc was also indicated. Two of the manufacturer's products contained halogens and two did not.

Future Activities Planned

1. Further testing is planned with the GSFC test device at AMC.

2. A test program will be conducted with the in-house adhesion test fixture; results will be correlated with those obtained from the GSFC device.

3. Lash Laboratories (Pyrotrak) tape will be evaluated for recording performance and temperature effects.

4. It is anticipated that a high-temperature tape will become available in sample quantities as a result of work being performed by the Memorex Corporation for GSFC. If samples become available, they will be evaluated.

INCREMENTAL MOTION TAPE DRIVE DEVELOPMENT - E. Bahm

The objectives of this subtask are to (1) determine the feasibility of transport ing magnetic tape with incremental motion in order to provide low and variable playback rates for spacecraft applications, (2) determine the electrical power requirements of such a tape transport, and (3) study problems associated with incremental playback.

General Background

Low data rates at playback and also variable rates can be achieved by transporting tape incrementally. Upon external command, the tape will be moved with relatively high speed, but only by a short increment. Such an increment will result in the playback of one or several bits/track. Tape motion is controlled from the information recorded on tape.

The main advantage of the incremental recorder is its flexibility at low and medium playback rates. It also avoids the low playback signal amplitude, normally associated with low playback rates.

Status

CPFF Contract 951289 was awarded to Ampex Corporation on August 24, 1965, for the development of a breadboard incremental motion tape transport. This transport (Fig. 1) was delivered to JPL together with a final report on April 27, 1966. The contract met all stated objectives. Digital information written on magnetic tape can be reproduced at any rate between 0 and 600 increments/sec if the recording density is less than 1000 flux reversals/in. and track. The power requirement for incremental operation is reasonable. All vital problems associated with incremental playback could be resolved.

Future Activities Planned

The performance and limitations of the incremental tape recorder will be studied further. A follow-on program will be outlined. It will probably ask for the development of a flightworthy incremental tape recorder suitable for Voyager capsule applications.

HIGH-IMPACT TAPE RECORDER DEVELOPMENT - E. Bahm

The objective of this task is to develop a tape transport for use in a hard landing capsule. This transport will have the capability of surviving thermal sterilization and a 6000-g shock. It will provide a total storage capacity of 1,000,000 bits. A representative tape transport is to be designed, fabricated, and subjected to environmental tests according to Voyager capsule test procedures.

Status

A bidders conference was held at JPL on January 27, 1966. Four proposals were received; three are considered technically responsive. However, the requirements for shock and sterilization had to be revised in view of the latest Voyager capsule requirements. Additional revisions are presently being studied. Incremental playback capability would be desirable for Voyager capsule applications in order to handle variable, low data rates. The latest results from the incremental motion tape drive development indicate that this is not unfeasible. However, the combination of high shock resistance, sterilizability, and incremental playback capability would be a difficult task.

Future Activities Planned

JPL Specification GMY-50492-DSN and Work Statement 399872 will be revised in view of the latest Voyager capsule requirements. A decision will be made whether incremental playback capability will be included, or not. It is expected that a contract can be awarded within the next reporting period.

MAGNETIC BEARING STUDY - E. Bahm

Magnetic bearings are advantageous for space applications. The lifetime of such a bearing is unlimited, and speed of the rotating element can be very high. Mechanical drag is negligible for most applications. The ideal environment is the vacuum. However, many obstacles and shortcomings limit the use of this bearing. A body can be kept in suspension by magnetic forces against only small axial and

radial forces; Earnshaw's Theorem shows that a magnet placed in the field of another magnet cannot remain in stable equilibrium.

Besides these two very severe limitations and the small chance of a success, it was decided to evaluate a new concept of a passive magnetic bearing. It is intended to circumvent Earnshaw's Theorem by using two independent magnetic bearings. Each bearing itself will be unstable; but it is hoped that the two bearings are capable of stabilizing each other.

Status

The JPL precision machine shop was unable to fabricate the magnetic bearing to the drawings. It is felt that this type of magnetic bearing cannot be built in small sizes, as required for spacecraft applications. The shapes of the individual parts are too complicated and the brittleness of most of the magnetic materials adds another difficulty. For these reasons, the study was terminated.

BRUSHLESS DC MOTOR DEVELOPMENT - E. Bahm

The objective of this development is to provide a family of brushless dc motors and associated control circuits for spacecraft applications. This family of motors will consist of two or three basic motor designs. All will be capable of being modified to meet different requirements. Several motor control circuits will be developed to further widen the applicability of these motors.

Brushless dc motors are expected to simplify future tape recorders. Speed-reduction devices will be simplified or even eliminated. Different tape speeds can be obtained by changing only motor speed. Very likely, this can be accomplished within a wide speed range, which at present requires a two-motor drive system.

Status

A contract has been awarded to H. C. Roters, Assoc., on February 9, 1966, for design, fabrication, and testing of a very small experimental motor. The design specifications are given in JPL TM 33-272, Vol. I, p. 183. Motor and sensor system have been designed, and fabrication has been initiated. The design of the switching electronics is nearly complete. The JPL concept for a reversible commutating system using only one set of shaft position sensors was adopted by the vendor.

A brushless dc motor of considerably larger size has been developed by H. C. Roters, Assoc., for GSFC. One unit has been ordered by JPL for evaluation purposes and will be delivered soon. This motor is not reversible. Necessary circuits will be developed to obtain reversibility. This motor design is provided for possible applications requiring high torque.

A new type of brushless dc motor is being developed in support of the incremental tape recorder effort. If the fabrication problems can be surmounted, this motor will have many of the unique characteristics, but not the disadvantages, of the printed circuit motor.

Future Activities Planned

The design of the switching electronics of the small motor will be completed and a speed servo will be designed. Motor and electronics will be fabricated. The large motor will be received and evaluated.

SERVOCONTROLLED TAPE RECORDER STUDY - E. Bahm

This effort has four objectives:

1. To synchronize a tape recorder at playback to an external clock at any high data rate.

2. To record variable rate data with constant recording density.

3. To operate a tape recorder motor at sufficiently slow speeds in order to reduce substantially the required speed reduction, or to eliminate speed-reduction devices completely.

4. To provide the capability of driving the magnetic tape at different speeds with one motor only.

General Background

The operation of a digital tape recorder together with a shift register was attempted in order to meet the above objectives. In the record mode, as well as in the reproduce mode, the shift register will act as a buffer between the recorder and the input-output. The tape recorder is controlled from the shift register to ensure that the shift register is always partially filled with data. Such a system places less stringent requirements on the tape motion. The data rates into and out of the recorder may momentarily deviate from the data rate requirement because the flow of data is smoothed out by the shift register. Even rapidly varying data rates can be accommodated. Also, the flutter requirement of the tape transport will be less stringent, thereby permitting the use of low-speed motors.

Status

A report was written describing briefly a possible design for the servocontrolled tape recorder system. A procurement package was prepared and RFP's were sent out to eight qualified companies. The program will utilize the engineering test model tape transport developed for Voyager. Until a brushless dc motor becomes available, a synchronous motor will be installed. This motor will be operated asynchronously and servocontrolled in exactly the same manner as a dc motor.

A competent proposal was received from Borg Warner Controls and is being evaluated.

Future Activities Planned

If additional funding can be provided, a contract will be awarded to Borg Warner Controls for the design, fabrication, and evaluation of a breadboard servocontrolled tape recorder system.

LOW-CAPACITY DYNAMIC STORE STUDY - E. Bahm

A study has been conducted to determine the device best suited for storage of between 100,000 and 1,000,000 bits of data. It is felt that neither solid-state memories nor available tape recorders are proper devices for the above capacity range. Solid-state memories are correct devices for storage of small amounts of data, but are complicated and bulky if their capacity is large. The tape recorder is a large-capacity storage device. If used for storage of small amounts of data, very often th record and playback times are short. The recorder then performs many record/ playback cycles within a short operating time. This results in a serious problem of tape wear. The operating life of a small capacity tape recorder, therefore, is limited.

Status

This study has been completed and is documented in JPL SPS 37-37, Vol. IV It was demonstrated that the tape-loop recorder and the magnetic drum can be used for the application described above. Both can be built for reliable operation in severe environments over long periods of time. The Titan Missile Drum built by IBM seems to be superior to tape recorders in some respects. Long lifetime and reliability are the main assets. In its present configuration, it is built for 600,000 bits total storage capacity, but it could be expanded further up to several million bits. This drum can be built for "no dropouts" by careful fabrication and inspection It is expected to remain free of dropouts during its entire life because the recording surface is never touched.

The main asset of the tape-loop recorder is the fact that it can be designed t withstand very high shock pulses and severe vibrations. The loop recorder is also believed to be capable of operating in a somewhat wider temperature range than the drum. Long life can be achieved by avoiding the tape splice and any contact of the recording surface with other parts. The tape splice can be eliminated by fabricatin the tape loop in a similar manner as seamless Polyester belts are made. Two tech niques have been used successfully.

1. Seamless magnetic tape loops have been fabricated from a coate Webb of Kapton polyimide (H-film), known as Pyrotrak. The be forming process did not deteriorate the magnetic coating to an intolerable degree.

2. The other technique used was fabrication of seamless polyester belts and subsequent plating on one side.

It was demonstrated during this study that contact of the recording surface with other parts can be avoided. The recording heads are pressed against the uncoated side of the magnetic tape, and recording is performed through the base material. With half-mil thickness of the base material, and recording densities of 600 bits/in., track could be easily obtained.

The operating life of such a tape-loop recorder is believed to approach the life of the magnetic drum.

ISO-ELASTIC TAPE TRANSPORT EVALUATION - J. K. Hoffman

This is a program for detailed evaluation of the iso-drive transport, which was designed to be an exact fundamental replacement for the endless loop type transport used in the Mariner Mars 1964 system. It includes testing and analysis to establish the relationships between performance characteristics, design criteria, environmental tests, and/or fabrication practices.

General Background

Results of type approval environmental and performance tests conducted during FY 1965 indicated the need for further analysis to investigate the cause and effect of some degradation in performance as reflected by an increase in flutter.

The transport was examined to determine general condition and fabrication techniques. The unit was disassembled, and a detailed dimensional analysis was conducted. Several rotating components were found to be out of specification, and the clutch assembly operation was inconsistent. It was concluded from the evaluation that some of the critical components were originally out of specification, and that dimensional discrepancies noted were not related to the type approval test program. However, new parts were fabricated, or existing ones reworked, as required to meet specification. New bearings and drive belts were obtained, and the process of reassembly was undertaken.

Activities During Report Period

Reassembly of the tape transport was completed. The unit was operated briefly, but stacking of the tape on the reels was unsatisfactory. Several attempts were made to remedy the condition by minor adjustments and belt substitution, but without significant success.

A reanalysis of the areas that could contribute to uneven and inconsistent stacking is in process. The alignment of all critical rotating components is being rechecked. Some calculations were made that indicate that belt tensions may be marginal, thus causing low or erratic tape tension and resulting in uneven stacking. The condition of the tape itself is not optimum, showing signs of distortion, which could have similar effects.

Future Activities Planned

Work will continue to solve the tape stacking problem. When this is accomplished, system performance tests will be conducted. The results will be comparatively evaluated with previous data to achieve the objectives of the program. A final report will be prepared.

BEARING AND LUBRICATION STUDY - J. K. Hoffman

Ball bearing failure is one of the more common causes of spacecraft tape recorder malfunction. Failure modes are complex involving many relationships of design and application. The objective of this task is to develop a better understanding of the underlying causes of bearing failures, and to determine the best bearing/lubricant combinations for the various classes of tape recorder bearing applications.

Also, it is expected that better understanding of the nature of bearing failure will facilitate improved bearing specification and screening.

General Background

Because the reliability of magnetic tape transports used in spacecraft applica tions has proved to be significantly dependent upon that of the bearing elements, a continuing program to investigate this important area has been instigated during this report period. The intent is to investigate and evaluate various bearings and bearin lubricants relative to their characteristics of torque, life, stability of operation, an environmental compatibility. Considerable paper research has been conducted for additional background in the subject.

Activities During Report Period

Several organizations specializing in bearing test and analysis have been visited, and their operations discussed. Several types of bearing test equipment considered for use in the subject program have been observed; their characteristics are being evaluated. These contacts, plus other research, have indicated that there is very little in the way of bearing test and evaluation equipment in use that has not been designed or modified to meet the specific requirements of the user. Consequently, procurement of bearing test equipment has been delayed pending a firming u of criteria by which a decision to buy, build, or buy and modify can be made. A number of candidate lubricants have been procured for testing. The cognizant engineer has recently completed a survey course in advanced bearing technology, providing basic technical background. A preliminary outline of general requirements o the evaluation program was prepared.

Future Activities Planned

Temperature tests of selected lubricant samples will be conducted. Efforts will continue toward definition and procurement of test equipment. Bearing test criteria will be firmed up, and bearings will be procured.

DRIVE BELT STUDY - J. K. Hoffman

The objective of this program is to study the characteristics of seamless polyester film drive belts relative to their use in spacecraft tape recorder transpor systems. Areas of investigation are the (1) belt fatigue life under conditions susceptible to statistical treatment, (2) effect of environment and fabrication technique on fatigue life, (3) development of a valid method of fatigue life prediction, and (4) coefficient of friction and stress relaxation characteristics.

General Background

Seamless belts were fabricated from polyester film, and tested using specially designed fixtures for fatigue life. The results were organized to provide a bas for reliability analysis and life prediction of belts used in practical applications. The fatigue life data are presented as a series of curves, each representing a given survival level at a known confidence level. Results indicate that the best fatigue lif is achieved using thin, narrow belts, and that there is a strong relationship betwee heat-treat time and length-to-width ratio in belt fabrication. Operating factors closely related in reliability prediction are: installed stress, threading pattern,

ılley diameter, transmitted torque, and belt dimensions and speed of operation. The nalysis of the coefficient of friction, creep, and stress relaxation characteristics, stablish time, temperature, and installed stress as important design criteria relave to torque capacity. Results indicate that the torque capacity of a system drops ıring storage periods at room temperature. However, an increase in capacity was oted at 150°F.

ctivities During Report Period

The study of polyester film belts was completed, and reports were prepared. rocurement was initiated for a follow-on study of polyimide (Kapton) film belts ıder NASA Work Unit 186-58-03-01-55 funding. Status is reported under that work ıit number.

UBLICATIONS DURING FY 1966

PL SPS Contribution

Bahm, E., "Low Capacity Dynamic Storage Devices," SPS 37-37, Vol. IV, February 28, 1966.

ontractor Reports

Karsh, I., "Tape Recorder Belt Study" (Final Report on Fatigue Life of Seamless Polyester and Polyimide Film Belts), Contract 950899, Kinelogic Corporation, November 1965.

Karsh, I., "Tape Recorder Belt Study" (Final Report on Belt-to-Pulley Creep, Coefficient of Friction, and Stress Relaxation of Seamless Polyester Belts), Contract 950899, Kinelogic Corporation, January 1966.

Karsh, I., "Tape Recorder Belt Study" (Final Report on Thermal Shrinkage of Polyester Base Magnetic Tape), Contract 950899, Kinelogic Corporation, January 1966.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

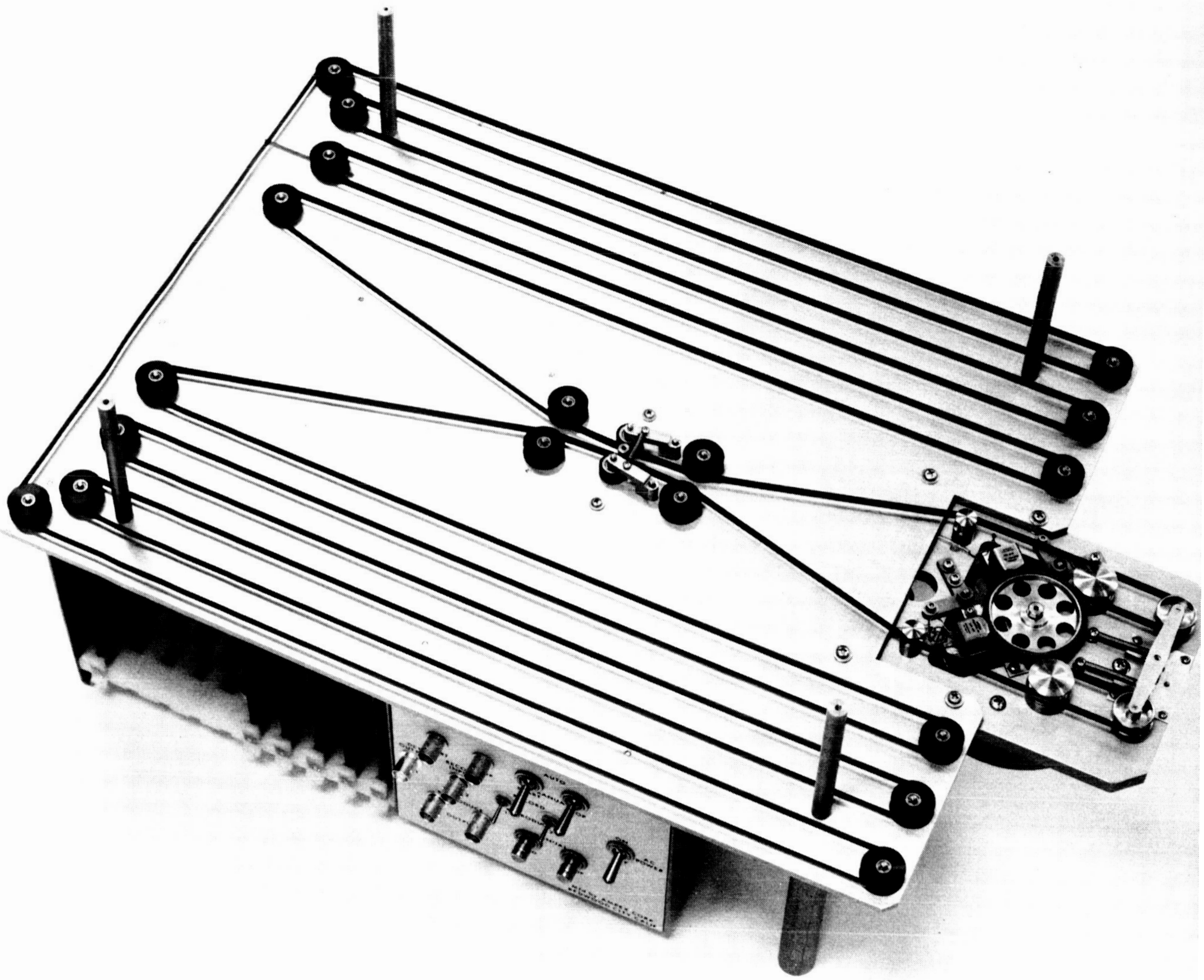

Fig. 1. Incremental motion tape transport breadboard

SPACECRAFT DATA SYSTEM SIMULATION

NASA Work Unit 186-68-03-03-55
JPL 384-60801-2-3240

M. Perlman

BJECTIVE

One long-range objective is to formulate concepts and analytical design chniques for synthesizing the spacecraft on-board science Data Automation Subystem. Specific subsystem functions will include data conversion, encoding, rmatting, processing, scientific instrument programming, and storing commands.

Another objective is to employ the general-purpose digital computer a tool in the design (e.g., minimization of logical elements) and analysis (e.g., gic simulation) of data automation equipment.

ROGRESS TO DATE

nalytical

An algorithm was formulated for synthesizing the detector of <u>any given binary quence</u> within a data stream. This is a generalization of the work reported in Binary Sequence Detectors," JPL SPS 37-31, Vol. IV, pp. 211-214. Figure 1 ows the state assignment determined by the algorithm for a sequential network to rve as a detector for the following 21-bit sequence:

1 0 0 0 1 1 0 0 1 0 1 0 1 1 1 1 1 0 0 0 0

. . . . .

21 15 10 5 1

e implementation of the detector is shown in Fig. 2. A writeup of the algorithm s been submitted to JPL SPS 37-40, Vol. IV.

A comprehensive study of counting techniques for a spacecraft science data ocessor was completed. The results of the study have been detailed and are being bmitted as a JPL Technical Report. Feedback Shift Register codes are the most omising for counting when serialization and simplicity of hardware are of paraount consideration.

e of General-Purpose Computer as a Design Aid

<u>Logic minimization.</u> A time-dependent voltage function of the form $V/(at+b)$ is quired by a particular type of mass spectrometer to be used in future planetary issions. Two approaches have been under investigation for generating the curve gitally. Both approaches involve the simultaneous minimization of Boolean funcns as outlined in JPL TM 33-272, Vol. 1, pp. 191-193. The approach in ich a Feedback Shift Register was used to generate 2^9 distinct combinations of ates was used. These states are to be translated to a fixed-weighted code by means a diode AND-OR matrix with 12-bit accuracy. The problem was tailored from 14 nctions of 11 variables to 11 functions of nine variables because the computer proam "Boolean Algebra Minimizer" Share Program LLBAM 1197 written in 1961

could not handle the larger set of functions. Furthermore, the outputs had to be partitioned into four sets of three functions of nine variables, a further comprom because of program limitations. A solution was obtained for the diode matrix. A diode count of slightly over 2000 diodes is required whereas a conservative estima of 8000 diodes would be required without minimization.

In view of the program limitation, a Statement of Work has been prepared t modify or completely rewrite the program if necessary to realize the theoretical potential of the size matrices to be minimized. The Statement of Work will be released either as an RFP or will be handled under contract with subcontractors a JPL.

Logic simulation. The Logic Simulation Program has been completed. Some difficulty has been encountered in the clock simulation. This will be rectified by th Planning Research Corporation (subcontractor who wrote the program at fixed cost which provided lectures at JPL to train JPL in the use of the Logic Simulation Program.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. Perlman, M., "An Algorithm for the Synthesis of Binary Sequence Detectors, SPS 37-39, Vol. IV, June 30, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

1. Perlman, M., "The Counting Task for a Spacecraft Science Data Processor," (to be submitted as a JPL TR).

x	d_1	d_2	d_3	d_4	d_5	Present State	d_1	d_2	d_3	d_4	d_5	x	d_1	d_2	d_3	d_4	d_5	d_1	d_2	d_3	d_4	d_5
0	0	1	0	0	0	1	0	0	1	0	0	1	0	1	0	0	0	0	1	0	0	0
0	0	0	1	0	0	2	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0
0	0	0	0	1	0	3	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0
0	0	0	0	0	1	4	1	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0
1	1	0	0	0	0	5	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
1	1	1	0	0	0	6	1	1	1	0	0	0	1	1	0	0	0	0	0	1	0	0
1	1	1	1	0	0	7	1	1	1	1	0	0	1	1	1	0	0	0	0	1	0	0
1	1	1	1	1	0	8	1	1	1	1	1	0	1	1	1	1	0	0	0	1	0	0
1	1	1	1	1	1	9	0	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0
0	0	1	1	1	1	10	1	0	1	1	1	1	0	1	1	1	1	0	1	0	0	0
1	1	0	1	1	1	11	0	1	0	1	1	0	1	0	1	1	1	0	0	0	1	0
0	0	1	0	1	1	12	1	0	1	0	1	1	0	1	0	1	1	0	1	0	0	0
1	1	0	1	0	1	13	0	1	0	1	0	0	1	0	1	0	1	0	0	0	1	0
0	0	1	0	1	0	14	0	0	1	0	1	1	0	1	0	1	0	0	1	0	0	0
0	0	0	1	0	1	15	1	0	0	1	0	1	0	0	1	0	1	0	1	0	0	0
1	1	0	0	1	0	16	1	1	0	0	1	0	1	0	0	1	0	0	0	0	0	1
1	1	1	0	0	1	17	0	1	1	0	0	0	1	1	0	0	1	0	0	1	0	0
0	0	1	1	0	0	18	0	0	1	1	0	1	0	1	1	0	0	0	1	0	0	0
0	0	0	1	1	0	19	0	0	0	1	1	1	0	0	1	1	0	0	1	0	0	0
0	0	0	0	1	1	20	1	0	0	0	1	1	0	0	0	1	1	0	1	0	0	0
1	1	0	0	0	1	21	0	1	0	0	0	0	1	0	0	0	1	1	0	0	0	0
0	0	0	1	1	1		∅	∅	∅	∅	∅	1	0	0	1	1	1	∅	∅	∅	∅	∅
0	0	1	0	0	1							1	0	1	0	0	1					
0	0	1	1	1	0							1	0	1	1	1	0					
0	1	0	0	1	1							1	1	0	0	1	1					
0	1	0	1	0	0							1	1	0	1	0	0					
0	1	1	0	1	0							1	1	1	0	1	0					
0	1	1	1	0	1							1	1	1	1	0	1					

Fig. 1. State assignment for detection of 21-bit sequence

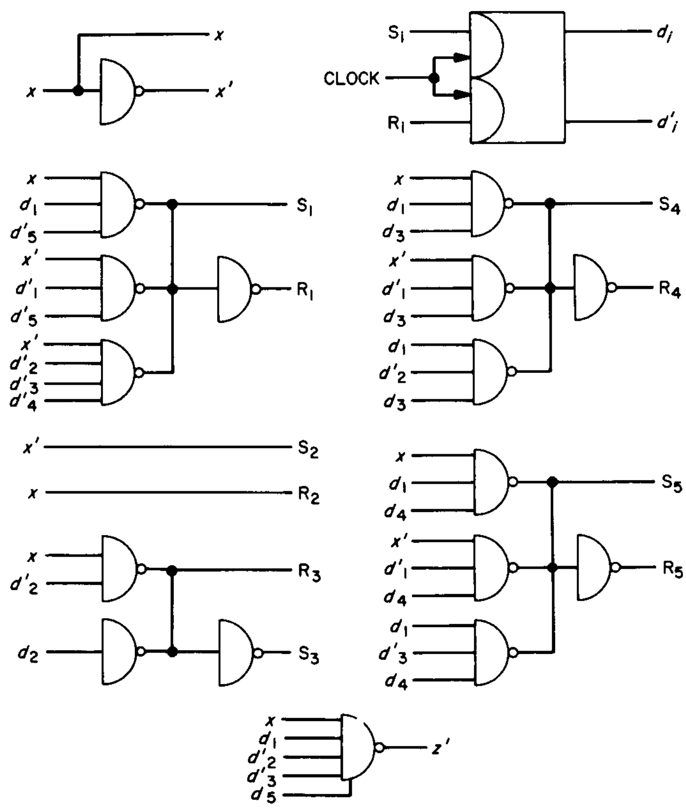

Fig. 2. Implementation of detector of 21-bit sequence

CAPSULE DATA HANDLING SYSTEM
NASA Work Unit 186-68-03-04-55
JPL 384-61601-2-3240
R. H. Nixon

BJECTIVE

The objective of this work unit is to develop concepts for the design of the ata acquisition circuits that are required to match the unique and peculiar data haracteristics of the scientific instruments to the realizable data-telecommunication ystem, while considering the severe constraints imposed by the capsule engineering mitations, including weight, power consumption, sterilization, shock, and lifetime.

ROGRESS

The design, specification, and acquisition of Automatic Data Processing quipment (ADPE) (Fig. 1) have been initiated to aid in the development of space-raft science data handling techniques. The status of the acquisition is:

1. Procurement requisition in the amount of $68,000 has been approved by JPL and OARD.

2. Plan for the acquisition of Category B ADPE has been forwarded to NASA and is awaiting approval.

3. Design of the data library control equipment using standard logic cards has been accomplished.

The objective of the overall system is to develop, through simulation, data ndling techniques that will optimize spacecraft science Data Automation Equipment AE) efficiency in information transfer, redundant encoding, programmable capa-lity or other techniques of increasing the confidence in the validity of the received ta.

A brief description of the functional blocks shown in Fig. 1 is given below for arification of the overall system function.

ta Library and Data Simulator

The data library is a facility that will acquire and store the data output of the rious interplanetary and planetary instruments that might be flown on future mis-ons. The sources of data may be an actual laboratory instrument, hand generated orst-case data, or actual data received from previous missions. The storage edia can be magnetic tape, punched cards, or punched paper tape.

The appropriate block of data from the data library is fed into the data simu-tor. The data simulator acts to simulate the data output characteristics of an tual instrument by direct control from the system control function (Block 3) and the ta processor simulator (Block 2).

Data Processor Simulator

The Data Processor Simulator is a general-purpose type digital computer programmed to perform a special data processing function on the data output of the data simulator.

System Control and Data Output

The system control function is composed of logic breadboards and special input/output equipment for controlling and programming the general-purpose comp ter. It is here that the special processing function of the computer is married to t logic breadboards that represent special control functions of the overall data syste

The data output equipment will reduce the processed data to a form similar that which might be received through the SFOF during an actual mission. Data in this form can be given to a cognizant experimenter for review and analysis to dete mine the validity of the data processing techniques used.

The primary function of the general-purpose computer is to act as a data processor and simulator in the system. The computer will be required to simulat the various functions of a spacecraft science data handling system. In this capacit some computational capability is required; however, the major function will be tha of a processor and simulator.

The utilization of the ADPE in the design and simulation of advanced scienc data processing equipment is discussed below:

Data Frame Formatting

Expected outputs of science instruments representative of a proposed scien payload are simulated on punched paper tape. Multiplexing (time-sharing) and for matting will be performed by the ADPE. This will result in a serial output to a buffer in which the order (hence address) of each word is known. Programmable changes in the format will be realizable through simulation of formats most suitab to a given set of science instruments. These results will be used in the organizati and the design of the spacecraft data processor.

Identification and Control Signals

The generation and detection of binary sequences for word and frame identi cation and control signals for sequential networks will be simulated on the ADP. most economical generator-detector (with attendant tradeoff) in terms of hardware complexity will be determined.

Data Compression

Zero and first-order sampling will be simulated on actual data runs to dete mine their effect on information transmission. The reconstruction of compressed data will be performed on the ADPE and compared with the raw data. Curve fittin and statistical methods will be applied to science instruments whose outputs are spectra (i. e., mass spectrometer and gas chromatograph).

Redundancy

1. Signal. Generalized parity checks will be added to data words to form cyclic algebraic group codes. Decoders will be simulated to determine the feasibility of incorporating error detection and error correction codes to increase the probability of errorless information transferral.

2. Circuit. Failures will be simulated by the ADPE. Quantitative reliability data will be extracted to determine if and where circuit redundancy (interwoven logic) can be exploited to enhance a Science Data Processor's reliability.

Programmable and Adaptive System Simulation

This is a long-range objective and will utilize the full capabilities of the ADPE in exercising decisional control of the bioscience class of experiments. In this mode of operation, the ADPE will work out details for future automatic data handling and control systems that must control the complicated sequencing of a capsule.

In addition to the processing and simulating function described, the computer will function as a bench checkout system for advanced data handling systems that may be constructed in breadboard or engineering model form. In this capacity, the computer would be hard-wired in the system for long periods of time.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

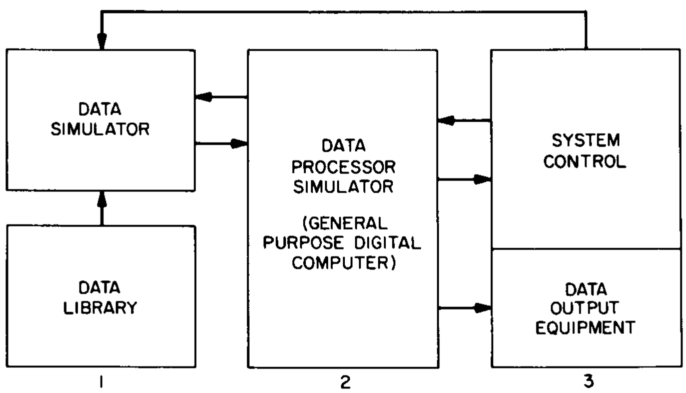

Fig. 1. Science data acquisition and processing system

SPACECRAFT DATA PROCESSING

NASA Work Unit 186-68-03-05-55
JPL 384-61701-2-3340
R. F. Trost

BJECTIVE

The primary objective of this work unit is to demonstrate the feasibility of an lvanced Engineering Data Handling System (EDHS). Feasibility will be demonstrated r hardware (including reliability, weight, and power costs) and efficiency of inforation transmission. A secondary objective is to provide meaningful information r later flight system development, design, and fabrication.

TRODUCTION

In the last quarter of FY 1965, a decision was made to embark on the developent of an Engineering Data Compression System and its attendant functions. Data mpression can be defined as the removal of redundancy from sensor signals. inctions attendant to data compression are confidence sampling, controlled redunncy introduction for operational measurements, data buffering, and priority lection during buffer overloading.

ATUS OF WORK UNIT

This work unit will be discontinued at the end of FY 1966. Consequently, the ocedure being followed is to logically document and phase out all present work by ly 1, 1966.

ROGRESS

HS Simulation

During the reporting period, simulation studies were completed of one of the bsystems of the EDHS. The simulation was performed on the SDS 930 computer; results were summarized in a JPL internal Technical Memorandum. Because of npower limitations and the short time remaining on this effort, generation of alistic spacecraft data for inputting to the simulation program was not initiated.

The EDHS was developed, studied, and logically designed on paper. Although hardware has been built yet, it is planned that the Telemetry and Command Group JPL Section 334 will continue to develop and construct small portions of the EDHS. ch a limited effort will be useful because certain subsystems and techniques can be oved valid before committing additional time and money.

riner IV Data Compression Investigations

A computer program was written for the IBM 7094 to study *a posteriori* the ects of data compression on actual Mariner IV engineering telemetry data. The emetry data was formatted on magnetic tape and processed for several different

compression algorithms. The best results were obtained for the zero-order compression algorithm. It produced an average gross compression ratio per char of 135 for 42 channels on the high and medium rate decks over a several-hour peri of the cruise mode.

SYMPOSIA

On February 15, 1966, a talk was presented by the author at the Adaptive Telemetry Conference sponsored by the Goddard Space Flight Center. The title o the talk was "*A Priori* and *A Posteriori* Studies of Adaptive Telemetry Techniques for Deep Space Missions."

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. Trost, R. F., "Advanced Data Processing," SPS 37-39, Vol. IV, June 30, 1

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

CRITICAL DATA RECORDER TELEMETRY SYSTEM DEVELOPMENT

NASA Work Unit 186-68-04-01-55
JPL 384-66001-2-3340

W. E. Arens

BJECTIVE

The objective of this work unit is to develop the telemetry system for the ritical Data Recorder (CDR) that will be capable of providing (1) touchdown diagnos- c data in the event that Surveyor telecommunications are lost during a nominal nding and (2) data relative to the nature of the lunar surface in the event of a ominal landing or a catastrophic landing (velocities in excess of 13 ft/sec but less an 600 ft/sec).

The primary function of the CDR spacecraft telemetry system will be to eceive, condition, process, store, and ultimately read out, through appropriate odulated subcarriers, data providing the following information:

1. Order of occurrence of "n" specified potential events.

2. Time elapsed between each of the above "n" events.

3. Fact of occurrence or nonoccurrence of "m" specified untimed events.

4. Touchdown acceleration/time profile providing rise time, peak g level, and profile duration.

ROGRESS

During this reporting period, a detailed final report was completed for the reliminary design of the CDR.

Other planned activities for this period were not accomplished because of an itial shortage of manpower and subsequent termination of the effort.

UTURE PLANS

This effort has been terminated in that it no longer represents a potential ntribution to the Surveyor mission.

UBLICATIONS DURING FY 1966

None.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

RADIO FREQUENCY TEST CONSOLE[1]

NASA Work Unit 186-68-04-03-55
JPL 384-61201-2-3341

F. J. Charles

ЗJECTIVE

The objective of this work unit is to develop the RF Test Console which, when mpleted, will be used as a precision laboratory tool to assist in the evaluation of rious telemetry techniques and their interaction with the RF system. The console ll be used extensively in support of the Capsule Telemetry Relay Link and the Caple Telemetry Direct Link tasks, spacecraft telemetry and video studies, and spaceaft and capsule command modulation systems development.

ιDIO FREQUENCY TEST CONSOLE, PHASE I CONTRACT

The RF Test Console Phase I contract (JPL 950144) was awarded to Westinguse Corporation, Baltimore, Maryland, on March 5, 1964. The primary goal of s contract was to build a precision 50-Mc signal-to-noise mixer and demonstrate perimentally that an RF signal-to-noise ratio could be set and maintained within a erance of ±0. 3 db over a 4-hr period. In addition, Westinghouse was required to ιdy practical methods of mechanizing an equivalent DSIF transmitter/receiver pair cluding possible future capability) with an accuracy and precision at least an order magnitude better than that obtainable from an operational DSIF transmitter/ ceiver pair.

The significant results and the conclusions reached during the course of this ntract are summarized in a final report. In addition, the detailed experimental and alytical work performed under this contract is available in the form of appendices the final report. For convenience, some of the more important results are ported here.

The primary aim of the contract was to establish the accuracy with which erage signal-to-noise ratios at 50 Mc could be set. Toward this end, a matrix of possible signal-to-noise settings (25 x 10^4 of them) was arranged into four quadnts; ten settings from each quadrant, plus the corner setting, were selected at ndom. The mean, variance, and standard deviation of each quadrant were calcued. By comparison, each quadrant was a subset of the total matrix population,and nean, variance, and standard deviation were calculated for all the readings. om these calculations, a 95% confidence interval with 5% tolerance limits was plied; it was determined that no more than 5% of the readings would fall outside of 155 db. In addition, as a result of extensive testing, the noise power spectral nsity at the signal-to-noise mixer output was determined within ±0. 05 db by the quency response of the mixer. A functional block diagram of the RF Test Console shown in Fig. 1.

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[1]his contract was completely funded in FY 1965. Consequently, it does not appear a formal task in FY 1966; however, the progress of the RF Test Console will be ported here and in subsequent reviews.

A design review of the contract was held at Westinghouse in Baltimore on March 10, 1965, with ten JPL representatives (selected from JPL Sections 331, 336, and 339) in attendance. The design review consisted of a presentation of the significant results of the study effort including the proposed methods for building RF Test Console. In addition, a demonstration was presented of the signal-to-no mixer, and the method of verifying the spectral uniformity of the noise at the mixe output using an SDS 910. There was unanimous agreement among the JPL atten that both the quality and quantity of the Westinghouse effort was well worth the m spent. The effort under Phase I was completed, including delivery of the final report, in March 1965.

RADIO FREQUENCY TEST CONSOLE, PHASE II CONTRACT

A second contract (JPL 951140) was awarded to Westinghouse on June 29, 1965, to complete the fabrication of the RF Test Console in accordance with the revised specification contained in the final report of Contract 950144. The initial effort on this contract was concentrated on the development of common circuits f use throughout the console. The console, which will consist of four cabinets, is organized on a module basis with the exception of the standard test equipment. It estimated that 70% of the RF Test Console is physically completed as of June 1, 1 The major portion of the remaining effort consists of subsystem and system testi The present schedule calls for delivery of the RF Test Console to JPL by Octobe 1966. Two papers, entitled "The Linear Signal and Noise Summer" and "Phase Locked Phase Modulator," were presented by the Westinghouse staff at the 1966 I International Communications Conference. In addition, a patent for an improved phase-lock loop system has been applied for by the Westinghouse personnel and t JPL cognizant engineer.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

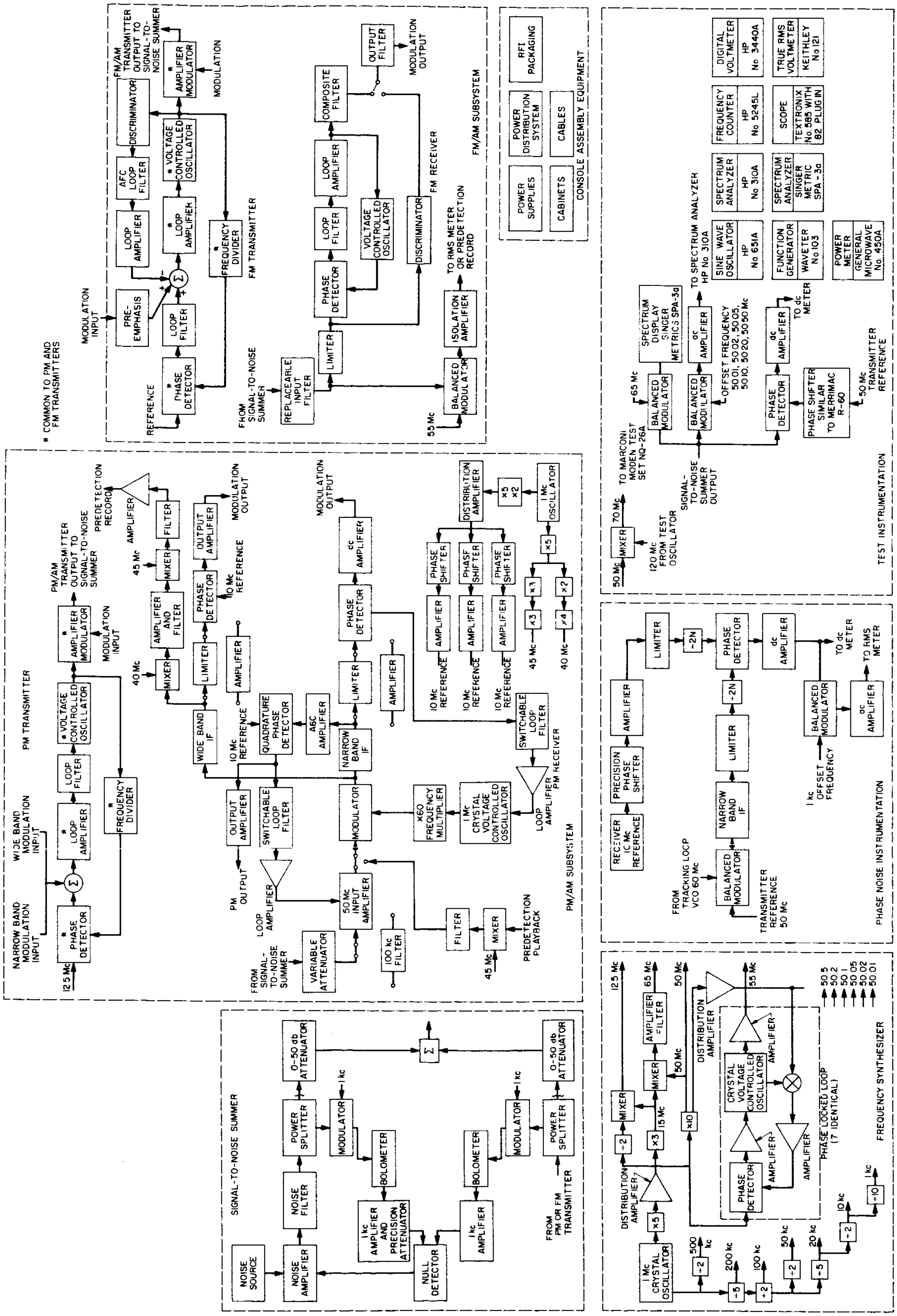


Fig. 1. Functional block diagram for RF test console

CAPSULE RELAY MODULATION SYSTEMS DEVELOPMENT

NASA Work Unit 186-68-04-04-55
JPL 384-61301-2-3340

J. C. Springett
D. J. Secor

JECTIVE

The objective of this work unit is to develop modulation, synchronization, and ling techniques applicable to the transmission of data from a landed planetary cap- e to an orbiting or flyby parent spacecraft at a bit-rate range of 10 to 200,000 s/sec. Feedthrough and full demodulation/detection systems will be studied; phasis will be placed on communication efficiency and reliability.

Studies and experimentation are being made on (1) double-sideband (DSB) and gle-sideband (SSB) phase modulation (PM) and frequency modulation(FM), problems associated with acquisition, (3) methods of bit and word synchronization, effects of nonlinear elements (limiters, etc.) used in the process of demodulation/ ection and remodulation of the spacecraft RF carrier, and (5) threshold criteria.

EORETICAL MODULATION STUDIES

Single-Sideband Phase Modulation (SSB-PM) is being studied for possible lication to capsule relay telemetry links in order to:

1. Relax some of the constraints imposed on DSB modulation approaches when a swept acquisition RF loop (automatic phase control receiver) is used.

2. Make maximum use of the available RF bandwidth that may be restricted by channel allocation and/or RF receiver design.

studies are intended to establish:

1. Spectral characteristics of SSB-PM signals.

2. Signal-to-noise performance of an SSB-PM receiver.

3. Problems associated with the implementation of an SSB-PM system.

The form of the modulated signal expressed in complex analytic form is en by

$$\underline{S}(t) = \exp\left\{\alpha\left[X(t) + j\hat{X}(t)\right]\right\}\exp(j\omega_0 t) \tag{1}$$

re $X(t)$ may be any low-pass periodic or aperiodic function possessing no singu- ities on $-\infty < t < \infty$, $\hat{X}(t)$ is its Hilbert transform, ω_0 is the carrier frequency, and a constant.

To obtain the power spectrum of $\underline{S}(t)$, it is necessary to evaluate the secon moment function of the modulating process, $X(t) \pm j\,\hat{X}(t)$. In an actual system, th modulation will be of such a form (e. g., binary) that the calculation of its second moment function is impractical, if not impossible. As a result, we have resorted a class of gaussian modulating signals with identical spectral characteristics as those of the actual modulation. Here, the complex second-moment function, $M_S(\tau$ has been shown to be

$$M_S(\tau) = \frac{1}{2}\exp(-j\omega_0\tau)\exp\left\{2a^2\left[R_X(\tau) - j\hat{R}_X(\tau)\right]\right\}$$

where $R_X(\tau)$ is the autocorrection function of $X(t)$, and $\hat{R}_X(\tau)$ is its Hilbert transfo

To evaluate the power spectrum, it is necessary to Fourier transform M_S using a computer for a given $R_X(\tau)$. Presented here are the results for a $\sin^4 \omega/$ modulating spectrum. Figure 1 shows the DSB spectra for various P_C/P_{TOT} (powe the carrier divided by the total power, often referred to as carrier suppression) i decibels; Fig. 2 shows the corresponding SSB spectra. Table 1 compares the sav of SSB over DSB for the various P_C/P_{TOT}. As can be seen, bandwidth savings o the order of 40% can be obtained for relatively high carrier suppressions.

EXPERIMENTAL MODULATION STUDIES

The breadboard modulator utilized the approximate Hilbert Transformer (described in the last semi-annual report. A higher order HT has been designed t should effect more suppression at high-modulation indices. Another SSB-PM mod lator utilizing the higher order HT has been built and is currently being tested in laboratory.

COMPUTER SIMULATION OF SSB MODULATION

The power spectral analysis of SSB-PM (see "Experimental Modulation Studies") was extended to SSB-PM with an approximate Hilbert transform. The SDS 930 computer was programmed to simulate the SSB-PM modulator, and resu were obtained for the approximate HT used in the laboratory breadboard model. comparison of the breadboard model and the simulation results is illustrated in Fi

A simulation of an SSB-PM utilizing the higher order HT mentioned previously been completed. The simulation indicated that more suppression at high-modulat indices could be obtained than were obtained with the first SSB-PM modulator.

A comparison of the simulation and the current breadboard modulator will published when testing is completed.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. Springett, J. C., "Some Experimental Results on the Noise Probability Dens Function out of a Bandpass Limiter," SPS 37-37, Vol. IV, April 30, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

Table 1. SSB and DSB comparison for $\sin^4 \omega/\omega^2$ modulating spectrum

P_C/P_{TOT}, db	Bandwidth to recover 85% of[a]		Bandwidth saving of SSB over DSB, %
	SSB power	DSB power	
- 0.5	2.5	4.8	48
- 1.0	2.7	5.2	48
- 2.0	2.95	5.6	47
- 3.0	3.25	6.0	46
- 4.0	3.75	6.6	43
- 5.0	4.3	7.2	41
- 7.0	5.4	9.0	40
-10.0	7.2	11.4	37

[a]Bandwidth relative to $\omega = 1$. The first null in the modulating spectrum occurs at $\omega = 2$.

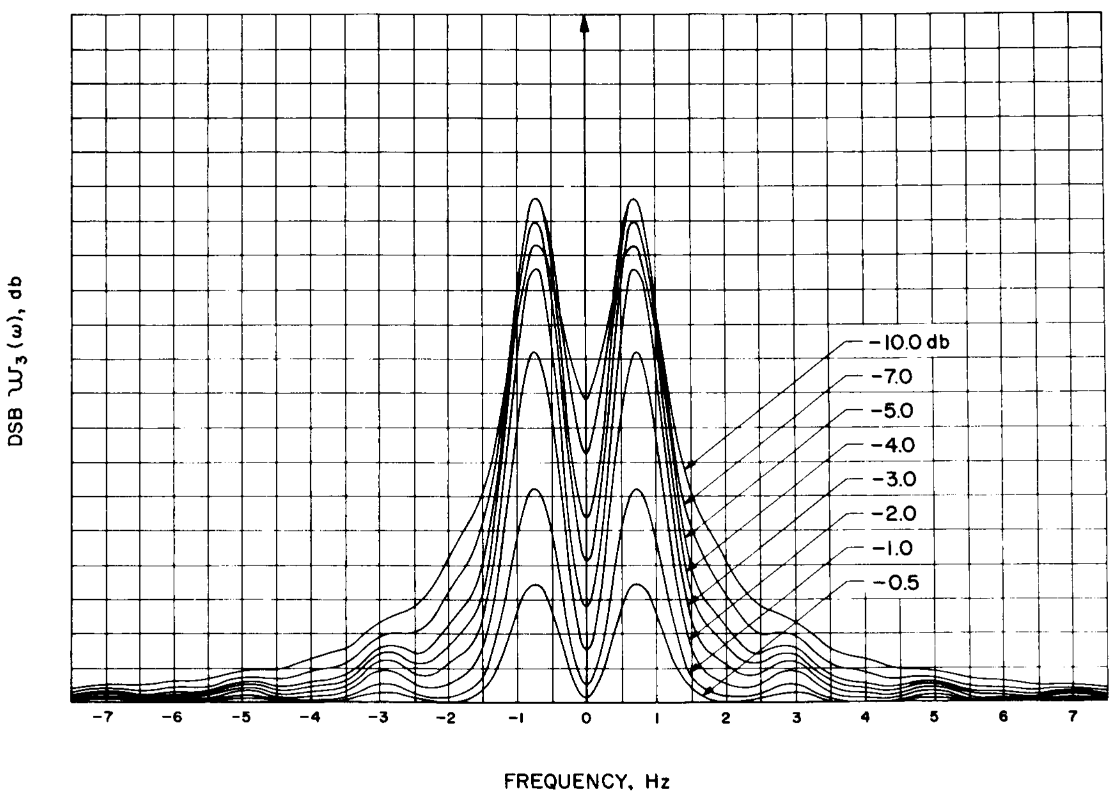


Fig. 1. DSB spectra for $\sin^4 \omega/\omega^2$ modulating spectrum

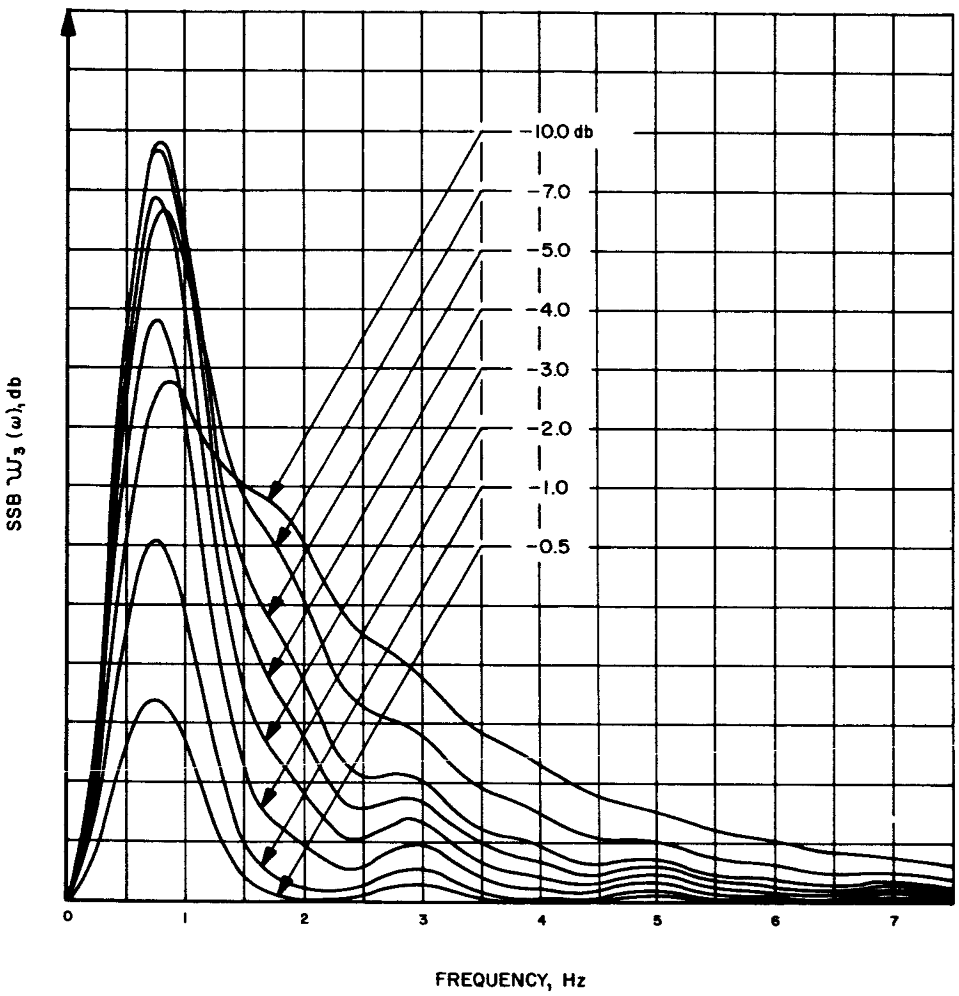


Fig. 2. SSB spectra for $\sin^4 \omega/\omega^2$ modulating spectrum

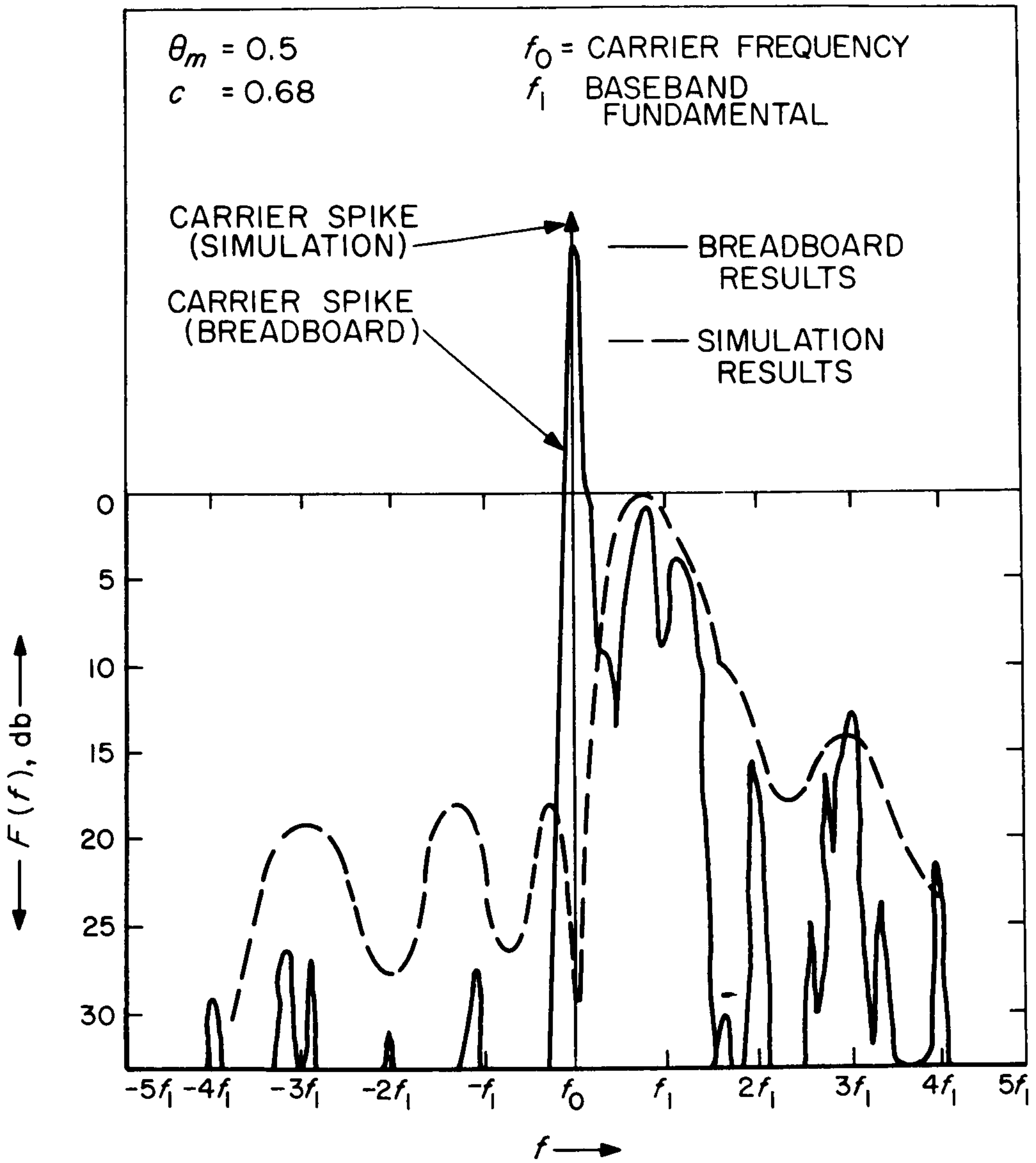


Fig. 3. Plots of SSB-PM spectra

CAPSULE ANTENNA STUDY

NASA Work Unit 186-68-04-06-55
JPL 384-61501-2-3360
K. E. Woo

3JECTIVE

The purpose of this task is to develop a series of S-band, low-gain, circularly larized, high-impact antennas. The present design objectives are the following:

Impact load: 10,000 g

VSWR: <1.2 at 2295 ±5 MHz

<1.3 at 2115 ±5 MHz

Gain: 4 to 8 db

Coverage: hemispheric, 3-db beamwidth ≤120 deg

Ellipticity: <6 db within ±60 deg from beam axis

Power handling capability: 100 to 500 w

s believed that the antenna requirements for most future planetary missions will l within the bounds of the above figures, although the exact characteristics will be tated by each mission specification.

3H-IMPACT LOW-GAIN ANTENNAS

Three types of high-impact antennas are in various stages of development:

1. Cavity-Backed Spiral Antenna. Figure 1 shows the modified version :he cavity-backed spiral antenna. To keep the feed point from fracturing when)jected to high impacts, the modified antenna utilizes a new stiffened circuit board 135 in. thick) and a ruggedized feeding system. The spirals are fed by a coaxial nsmission line protruding into the cavity from the rear, as shown in Fig. 2 and 3. threaded top of the center conductor (0.062-in. dia) is connected to one spiral n by means of a nut (0-80 thread). The outer conductor is connected to the other ral arm by means of a screw (0-80 thread).

High-impact tests showed that the modified antenna survived a 10,000-g impact lied in the direction perpendicular to the circuit board. However, the nut and the ew making the electrical contacts were found to be slightly loosened. As a result, ne deterioration in antenna performance was evident. Table 1 shows the antenna racteristics before and after impact, measured at 2298 MHz:

Table 1. Antenna performance before and after impact

Electrical characteristics	Before impact	After impact
VSWR	2.3	2.75
Gain, db	4.1	3.3
3-db beamwidth, deg	82	81
Ellipticity within 3-db beamwidth, db	<2.05	<2.80

The relatively high VSWR and low gain before impact were attributed to the misma in the transmission line, which can easily be corrected and will be done in the nex model.

Means of securing the feed contacts are being investigated. One method is t widen the spacing between the input arms of the spirals so that a stronger center conductor and ground screw can be employed. A circuit board designed and made this purpose is shown in Fig. 4a. For comparison, the circuit board of the modif antenna is shown in Fig. 4b.

2. Cupped Turnstile Antenna. The fabrication of the turnstile antenna wi cylindrical cup has been completed. As shown in Fig. 5, the turnstile elements a driven by an open-circuited quarter-wavelength balun and are completely recesse the cup for protection against impact. Measurements are being made to determin the electrical performance of the antenna.

3. Annular Slot Antenna. Electrical measurements of the annular-slot antenna are in progress. The antenna (Fig. 6) is excited by two orthogonally loca probes that are fed with equal power in time quadrature.

Several other radiating structures are currently under consideration for pos sible use as high-impact-survival antennas. These include:

1. A pair of crossed slots cut into the broad wall of a rectangular wa guide propagating the TE_{10} mode.

2. A square waveguide that is fed by two orthogonally located inputs.

3. A rectangular waveguide that is excited by a probe slanted betwee two adjacent side walls.

During the coming fiscal year, the above mentioned antennas, as well as ot types found to have merit, will be studied and compared. A design considered to have the best chance of meeting the Voyager 1973 mission requirements will be selected for prototype development in early FY 1968.

JBLICATIONS DURING FY 1966

None.

JBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

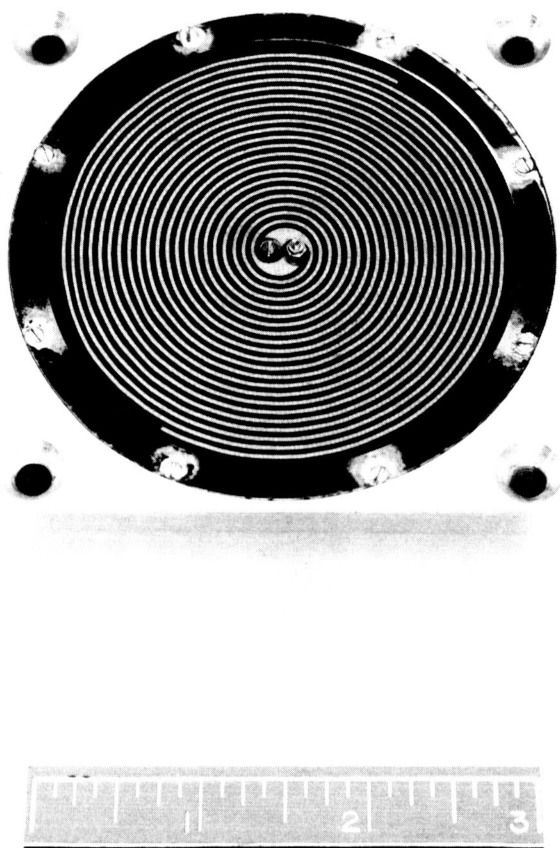


Fig. 1. Modified cavity-backed spiral antenna

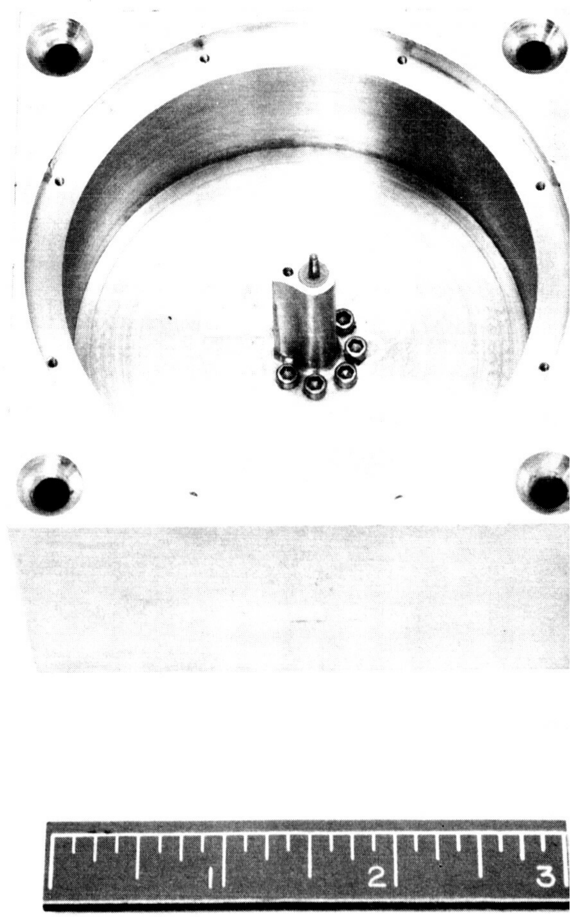


Fig. 2. Interior view of spiral antenna

Fig. 3. Rear view of spiral antenna

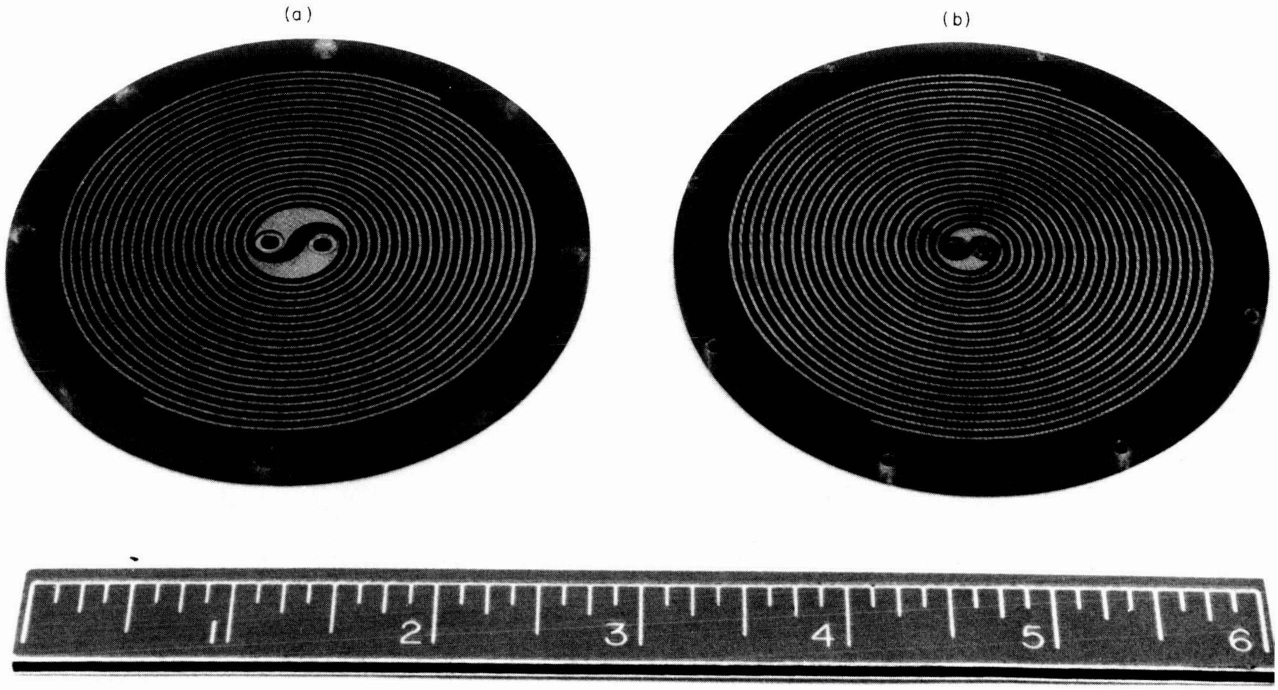
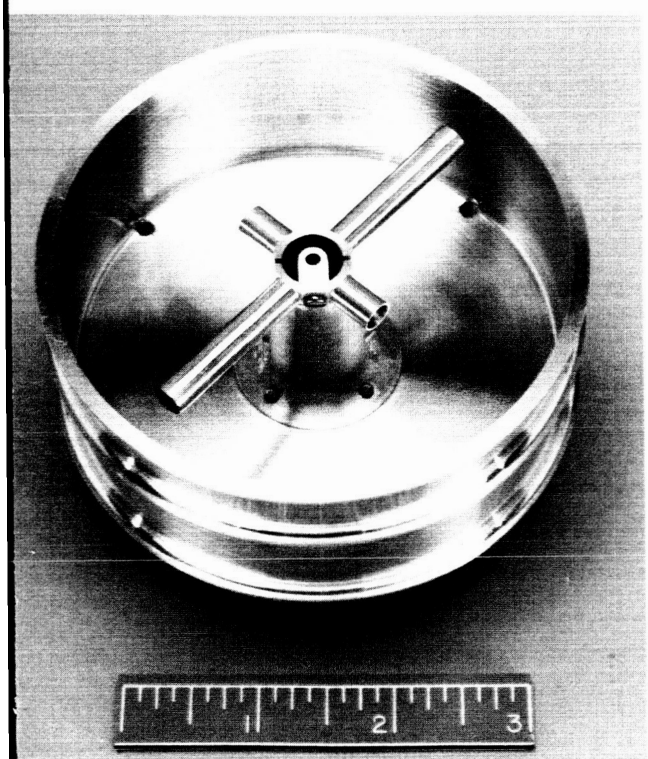


Fig. 4. Circuit-board design of spiral antenna



'ig. 5. Cupped-turnstile antenna

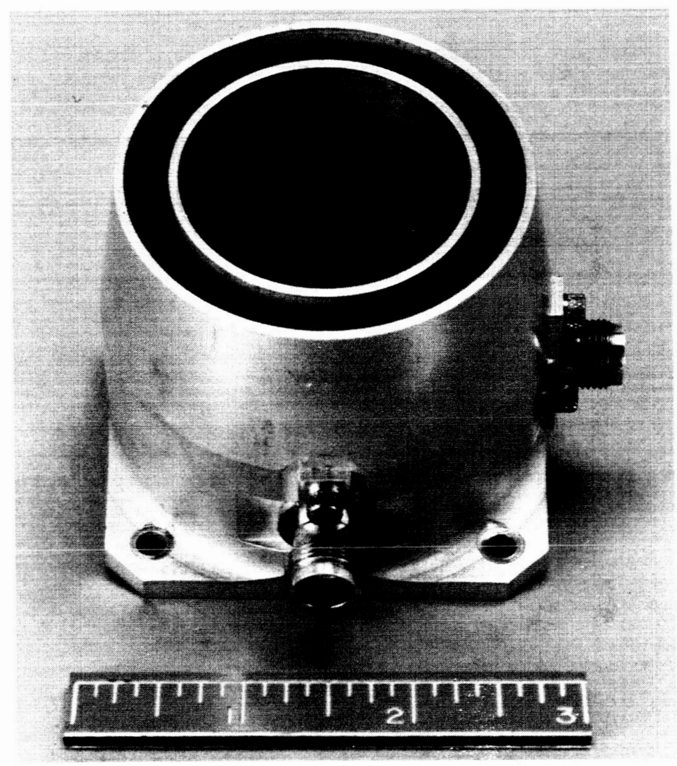


Fig. 6. Annular-slot antenna

CAPSULE RF RELAY

NASA Work Unit 186-68-04-08-55
JPL 384-63101-2-3360
R. B. Postal
C. M. Potts

)BJECTIVE

The present objective is to perform the engineering required to develop a)rototype UHF transmitter for a capsule-to-bus RF relay system. The 15-w, 400-AHz transmitter presently under development is a lightweight UHF unit that will sur-ive a high-impact landing on a planetary surface and operate in that environment. 'he long-range goal is a 100-w transmitter that will operate during capsule cruise nd entry modes.

In January 1966, the automatic-acquisition receiver experiments and studies, 'hich were included in the previously reported objectives and status, were termi-ated. It is presently planned to start receiver development in FY 1968.

APSULE TRANSMITTER

The transmitter is being developed in-house, taking advantage of much of the esign of the S-band transmitter being developed under the Low Data Rate Telemetry F Systems Development (150-22-05-17-55). The relay transmitter, as shown in ig. 1, consists of the VHF portion of the S-band unit (191-MHz, 20-w point) which retuned to 200 MHz and increased in power output to 24 w, and followed by a aractor doubler. An engineering model of the transmitter without the final doubler as successfully passed the 10,000-g shock test. Thermal tests will be performed aring the next reporting period. The breadboard model of the final doubler fur-shed 15 w at 400 MHz. Thermal and high-impact tests on the final doubler are to ke place during the next reporting period. The high-impact work is heavily sup-rted by 186-68-04-14-55, High Impact Communications Subsystem Technology.

The requirement imposed on the transmitter to survive a high impact landing on planetary surface dictates the need for a high impact, sterilizable quartz crystal. evelopment of this crystal is being accomplished and is reported under NASA 0-22-05-17-55, Low Data Rate Telemetry RF Systems Development.

JBLICATIONS DURING FY 1966

None.

JBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

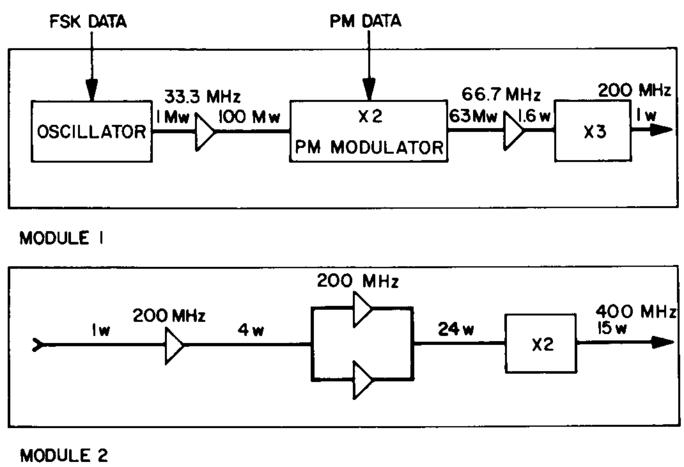


Fig. 1. Capsule relay 400-MHz high-impact, solid-state transmitter

RF POWER AMPLIFIERS

NASA Work Unit 186-68-04-09-55
JPL 384-63401-2-3360
L. J. Derr
R. S. Hughes

BJECTIVE

This effort is a continuation of the FY 1965 effort as presented to NASA adquarters on October 15, 1964, modified at JPL on September 27, 1965, and viewed for NASA personnel at JPL on April 15, 1966. The objectives are: (1) to velop S-Band RF power amplifiers for approved spaceflight missions, (2) to crease the available RF power levels consistent with projected spacecraft needs and pabilities (currently estimated to be 20 to 500 w for the Voyager and Advanced anetary programs), (3) to improve the efficiency, stability, reliability, and operng life of RF power amplifiers, and (4) to develop efficient heat dissipation techques for RF power amplifiers.

ECTROSTATICALLY FOCUSED AMPLIFIER (ESFA) DEVELOPMENT - JPL NTRACT 951195

The purpose of this contract is to develop variable power (20 to 100 w and 100 500 w) RF amplifiers employing a hybrid RF circuit design, electrostatic focusing, d a radiation-cooled collector system. The contract is divided into four phases:

1. Development of a 20- to 100-w tube.
2. Production of five 20- to 100-w tubes for life test.
3. Development of a 100- to 500-w tube.
4. Production of five 100- to 500-w tubes for life test.

velopment of the 20- to 100-w tube was initially funded from carry-over FY 1964, DA (311-03-53-52) money ($206,000), and the contract was signed with Eitel Cullough May 10, 1965. One year later, in May 1966, a projected overrun conion existed on this contract in the amount of $61,000. This work unit funded the ount from FY 1966 money. More than half of the overrun was caused by overhead/ A rate adjustments.

The 20 to 100-w design (see Fig. 1) has progressed considerably during this orting period. Two experimental tubes with water-cooled collectors have been lt and tested. The parameters of gain, bandwidth, and power variability have ched the specified values. Two separate test vehicles have demonstrated the quacy of the heat radiating collector design. Table 1 compares the specified ues with those measured. There remains considerable improvement to be made ube efficiency (37% realized vs 45% specified). The present effort is primarily centrated on efficiency improvement, and some delay in delivery is expected to ult.

Table 1. Specified and measured values, 20- to 100-w tube

Characteristic	20 w		100 w	
	Specified	Measured	Specified	Measured
Gain, db	30	32	30	40
Bandwidth, MHz	30	32	30	32
Thermal radiation efficiency, %	60	80	60	75
Overall RF efficiency, %	35	29.5	45	37

Production of the five tubes for life test will be funded by this work unit in FY 1967 in the amount of $95,000. This portion contains no development effort and will not be authorized to begin until the development work has been completed successfully.

Development of the 100- to 500-w tubes was partially funded in FY 1966 from NASA 186-68-04-15-55 money ($150,000). An additional $120,000 will be needed to complete this phase. FY 1967 funds under work unit 186-68-04-09-55 will partially ($40,000) cover these costs. This phase 3 development will not be authorized to proceed until phase 1 has proven the capabilities of the hybrid design.

HIGH EFFICIENCY TWT DEVELOPMENT - JPL CONTRACT 951299

This development seeks to advance efficiency in traveling wave tube design. The development goal is 55% at 100 w RF output. The tube will be conduction cool magnetically focused, and will employ a dual helix design. The contract, which w signed with the Watkins Johnson Company April 12, 1966, is divided into two parts

1. Development of the 100-w tube.

2. Production of five 100-w tubes for life test.

Development was partially funded ($140,000) by this work unit in FY 1965, and an additional $40,000 was provided by this work unit in FY 1966.

The basic design of the tube is now under way and a satisfactory developmen schedule has been prepared by the vendor.

JBE EVALUATION PROGRAM

The evaluation of commercial amplifiers serves two main purposes:

1. To advance our knowledge and, thus, improve our capability, for both in-house development and direction of the outside development contracts now underway.

2. To determine the applicability of each amplifier to future NASA programs.

The RF evaluation of the Hughes 20/5 w TWT, model 349H, under static condi-ns has been completed. The tube has a saturated gain of 25 db at both the 20- and w levels. Overall efficiencies of 32% and 24% were measured at the 20- and 5-w vels, respectively. A hysteresis was found in the gain curve (see Fig. 1) when the pedance of the helix supply was 5000 Ω or more. Environmental tests on this tube ould be completed early in FY 1967.

The RF evaluation of the Litton 20-w ESFA, model L-3910B, is complete. The e has a saturated gain of 23 db, an overall efficiency of 21%, and a 3-db bandwidth 3 MHz. A thermal test (see Fig. 2) revealed that, at 57°C, the RF output was b below its value at 25°C. Since there is no long-life-test data available on FK's, a life test will be conducted on the tube.

A total of $37,000 was spent for power-amplifier test equipment during FY 1966. is equipment is required for the evaluation and life testing of commercial tubes and he tubes resulting from development contracts of this work unit.

BLICATIONS DURING FY 1966

L SPS Contributions

1. Derr, L., "Spacecraft Power Amplifier Development Program," SPS No. 37-37, Vol. VI, p. 258.

2. "Environmental Temperature Control Analysis for Radiation Cooled RF Tubes - Development Test Setup," SPS No. 37-37, Vol. VI, p. 26.

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

1. Lien, E., "Radiation Cooled, Hybrid Tubes," (Provisional) Sixth International Conference on Microwave and Optical Generation and Amplification, sponsored by IEEE, to be held at Cambridge University, Great Britain, September 12-16, 1966.

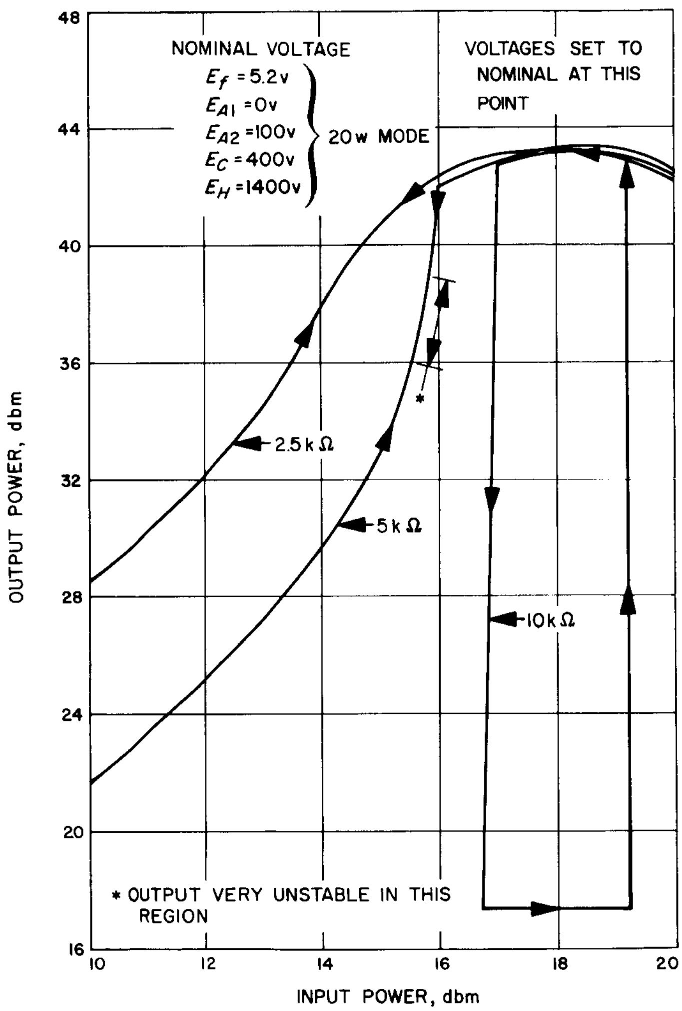


Fig. 1. Gain curves with 2.5, 5, and 10 k helix supply, Hughes TWT model 349H, S/N 159

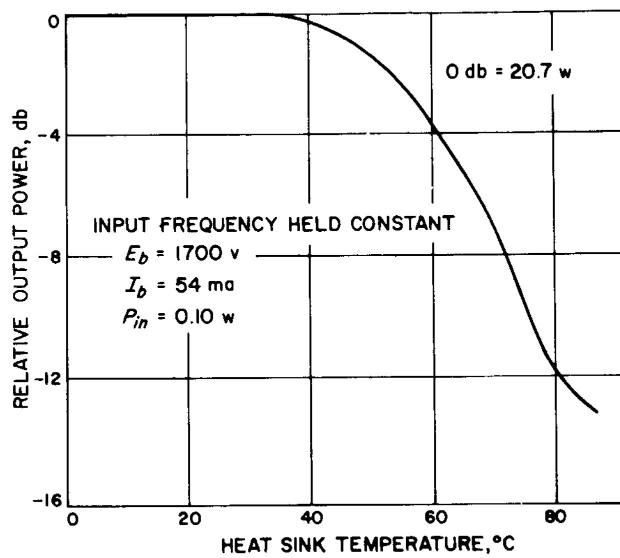


Fig. 2. Power output vs temperatur
Litton 20-w ESFA, model
L-3910 B, S/N 12

ADVANCED SPACECRAFT TELECOMMUNICATION SYSTEMS

NASA Work Unit 186-68-04-11-55
JPL 384-63201-2-3360
C. E. Gilchriest
M. A. Koerner
D. W. Boyd
M. K. Tam*

3JECTIVE

The objectives of this work unit are to provide the telecommunication system alysis and synthesis for advanced spacecraft missions and to coordinate the R/AD rk units that relate to the development of such system elements as transmitters, ceivers, modulators, demodulators, encoders, and decoders.

TIVITIES

liability Research

The long-range objective of this task, to develop methodology for the realistic sessment and synthesis of telecommunication systems, is largely accomplished rough a contract with Tam Research Associates, which was reactivated during this riod. This contract covers an eighteen month period at a labor cost of $36, 000.

During this reporting period, two subjects have been investigated. The first is investigation of the variability of estimated system reliability as influenced by the rious degrees of detail in the analytical model used. The various degrees of alytical detail can range from the non-discriminating parts count of the entire sysn to a complete consideration of the failure modes and partial successes of every nute piece-part within the system. A study of three different systems with various grees of analytical detail indicated that the reliability figure increased with the alytical detail; this higher figure resulted principally from obvious redundancies, rtial successes, and nonessential parts being accounted for.

The second area of investigation is the development of a methodology for taining a probability distribution function for the failure parameter of component rts. Sampling distributions for reliability tests are being investigated to identify robability distribution function for the failure parameter.

nal-to-Noise Ratio Estimator (SNORE)

The objective of this task has been to develop methods and hardware suitable monitoring the signal-to-noise ratio of the carrier, subcarrier, and synchronition channels for all projects that might interface with the DSIF.

Work has continued on the analysis of the device as designed for use in the riner C telemetry demodulator. Specifically, the following described analyses re performed.

ontract Associate

Self-Calibration of the SNORE. A fairly simple means of calibrating the SNORE has been developed. It requires that a square wave plus a dc level be use as inputs to the SNORE. To obtain different calibrating SNR's, only the level has be changed.

Errors in SNR Estimation at Low SNR. The analysis of the measurement accuracy of the SNORE has concentrated previously on errors that are important high SNR. To complete the picture, a brief analysis has been made of the errors occurring at lower SNR.

Monitoring PCM/FM. The SNR monitoring problem for a PCM/FM teleme channel was investigated. The results indicate that, for high SNR and an ideal detector, a monitoring system such as in the present SNORE would be adequate.

Effect of Line Noise on the Measurement Accuracy of the SNORE. An analy of the effect of line noise on the measurement accuracy of the SNORE was perfor Rough experimental values of the line noise were used to calculate a figure of me for the system. The results can be used to accomplish two tasks:

1. Predict the limitations imposed by line noise on the dynamic measuring range.

2. Formulate hardware specifications.

Effect of Offset Voltages on the Measurement Accuracy of the SNORE. The effect of offset voltages on system accuracy was calculated. System performanc was measured by using a figure of merit. The results can be used for the same purposes as those above.

Effect of the Digital Instrumentation System (DIS) Quantization on the SNR a the Output of the SNORE. The effect of quantization on the output SNR was determined. The results can be used to partially determine the effects of quanti tion on system performance.

The Effect of the Maximum Scale of the A-D Converter of the DIS on the Measurement Accuracy of the SNORE. An optimum and a practical solutic to the gain-setting problem caused by the maximum scale of the A-D converter w discussed. The results relate the errors caused by truncation, offset voltages, quantization, and line noise.

The Effect of the Invalid Gaussian Assumption on the Measurement Accura of the SNORE at SNR's < 10 db. A brief analysis of errors occurring at lo SNR's was made to round out the previous analyses, most of which concentrated higher SNR's.

The Effect of Computer Processing on the Measurement Accuracy of the SN

The limitations on the accuracy of the SNR measurement imposed by (1) T number of significant digits available at the output of the quantizer, and (2) the method of computations was determined.

pletion of the Analysis of the SNR Monitoring Problem for an Idealized
ıuency Shift Keyed System

The required processing is the same as for a phase shift keyed system.

In addition, the 1966 IEEE International Communications Conference was ıded in support of this task.

ysis of Cascaded, Frequency-Multiplexed PM Communication System Using
ıling Channels with Zero-Law Limiters

The system to be analyzed is a series of cascaded stages. Each stage includes equency-multiplexed, PM communication system, and a coupling channel. Prin- l elements of the frequency-multiplexed, PM communication system are a smitter and a receiver. The coupling channel connects the receiver output of one e through a high-pass filter and a zero-law limiter to the transmitter of the next e. Angle-modulated sine waves or binary-valued signals may phase modulate the smitted RF carrier of each PM communication system. Extractors for the rmation carried by these signals may process the output of any receiver follow- he point in the system at which the signals are introduced. The objective of this is to simplify the problem of evaluating this system as compared with that of uating the performance of an extractor in obtaining the required information from bcarrier signal, distortion, and white gaussian noise.

The objective will be satisfied by (1) demonstrating that, over the frequency of interest, the power spectral density of the gaussian noise at the receiver ut is the same as that of the gaussian noise at the receiver input, (2) deriving tions for the amplitudes of the signal-times-signal (SxS) components of the iver input and output, and (3) obtaining an upper bound on the power spectral ity of the signal-times-noise (SxN) components of the receiver input and output. each extractor that processes a receiver output to recover the information ied by an angle-modulated sine wave or binary-valued signal, one of the SxS ponents of the receiver output will be the desired signal. The remaining SxS ponents and the SxN component of the receiver output are distortion.

Derivation of the mathematical equations for this analysis had been completed f the last progress report.

During this reporting period, one immediate objective has been the revision of '094 computer program required to obtain numerical results. The revision is g made (1) to incorporate the changes which have been made to the mathematical ysis, (2) to break the computer program into subroutines which can be indepen- ly checked out, (3) to convert the computer program from the FORTRAN II to the TRAN IV language, to avoid use of an obsolescent compiler, (4) to add automatic ing, and (5) to extend the capability of the program to permit numerical calcula- for cases where the spacecraft receiver static phase error is non-zero. To ıate the effect of computer roundoff error on the accuracy of the numerical cal- ions, it is planned to develop both a single- and a double-precision version of computer program.

The first step in this revision is the development of a Bessel function outine capable of handling large arguments. The Bessel function terms lie in the range of a summation whose summation index is a factor in the argument

of each of the Bessel function terms. Under some conditions the summation ma converge slowly, and a large number of terms must be summed to obtain the required accuracy. This implies a requirement for a Bessel function subroutin capable of accurately evaluating Bessel functions of integer order less than 20 fo arguments as large as 1000.

Both single- and double-precision Bessel function subroutines have been written for integer orders; each uses the backward recurrence method to evalua the Bessel function. The subroutines have been checked against tabulated data f orders 0, 1, 2 and 3, for arguments between 0 and 100.

The next step in this revision is the development of a subroutine for $\log_{10}$(The double-precision version of this subroutine has been written and checked ag tabulated data for $0 \leq N \leq 1000$. Preparation of the analysis for publication is 70 completed.

Effect of Sinusoidal and Gaussian Interference on a Maximum-Likelihood Extrac for Binary Data from Antipodal, Binary-Valued Signals in White Gaussian Noise

The objective of this analysis is to determine the amount that a maximum likelihood extractor for binary data from antipodal, binary-valued signals in wh gaussian noise is degraded by the presence of a sinusoidal or gaussian interferi signal.

Exact expressions can be derived for the bit error probability in both the presence and the absence of the interference. The degradation is simply the fa by which the ratio of the received signal energy/bit to the noise spectral density the extractor input must be increased to reduce the bit error probability in the presence of interference to that which would exist in the absence of the interfer

Derivations of the mathematical equations for the bit error probability an the degradation for a sinusoidal interfering signal had been completed as of the report. During this reporting period, the analysis was extended to include gaus interfering signals.

The computer programs required to provide numerical results have been completely rewritten. Both a single- and a double-precision version of the pro have been written. As the single-precision version is appreciably faster than t double-precision version of the program, the single-precision program will be for production and the double-precision program will be used to spot-check the results of the signal-precision program.

The computer program has been revised to calculate the degradation for a gaussian interfering signal and to compare this result with the degradation for a sinusoidal interfering signal. In most cases of practical interest, the degradat gaussian signal produces is greater than that produced by a sine wave with the s power at the output of the maximum-likelihood extractor.

The computer program has also been revised to have the capability of plo experimental data over theoretically calculated curves.

Experimental studies to verify the accuracy of this analysis have not been planned. However, some experimental data was measured during Apollo Unifie S-band telecommunication system tests performed for MSC for Motorola. The

xperimental data will be plotted over the appropriate theoretical curves and ublished in the final report on this analysis.

ffect of the Frequency Response of a Turnaround Ranging Channel on Ranging ystem Performance

Existing analysis of the ranging system performance assumes that the ranging ignal is not appreciably distorted by the turnaround ranging channel. The objective f this analysis is to determine the effect that the frequency responses of the DSN ansmitter, the spacecraft transponder, and the DSN receiver have on ranging ystem performance.

Distortion of the ranging signal in the DSN transmitter, the spacecraft ansponder, and the DSN receiver will alter the cross-correlation function between e received ranging signal and signals generated by the ground ranging system. The nalysis is required (1) to evaluate the effect of the distortion on the cross-orrelation functions and (2) to evaluate the effect of distorted cross-correlation nctions on ranging system performance.

A preliminary examination of the system to be analyzed indicates that the fect of the ranging turnaround channel on the ranging signal is equivalent to that of o linear filters separated by a non-linear, zero-memory element with the transfer nction $y(x) = \mathrm{ERF}(\eta^{1/2}x)$. The first linear filter represents the net frequency sponse of the system preceding the limiter, which is in the channel that couples e spacecraft receiver output to the spacecraft transmitter input. The second near filter represents the net frequency response of the system following this miter. η is the signal-to-noise ratio which would be observed at the limiter input the distortion of the ranging signal by the DSN-spacecraft link were negligible.

The principal difficulty in this analysis is the evaluation of the cross-correlation tween signals generated by the ground ranging system and the output of the non-near, zero-memory element. Except in certain cases, where asymptotic results n be obtained, these cross-correlation functions must be evaluated numerically. nile this method may be feasible for short codes, it is not practical for the com-ex ranging code used in the Mark I ranging system.

Some asymptotic results can be obtained that will be of considerable value. r $\eta \ll 1$, $y(x)$ is asymptotically linear, and the overall response of the ranging rnaround channel is linear. Evaluation of the effect of a linear system on cross-rrelation functions is a relatively simple problem. For $\eta \ll 1$, $y(x)$ is a zero-law niter. Provided the net impulse response $\eta_1(\tau)$ of the DSN-spacecraft link is gligible for $\tau > \tau_0$, where τ_0 is the symbol duration of the ranging code, the niter will regenerate the original ranging signal with only a time delay equal to net time delay through the DSN-spacecraft link at the ranging system clock equency.

The first step in a detailed analysis of this system is the justification of the nplified analytical model. At present, this step is completed for the DSN-acecraft link.

This analysis is being performed in support of a contract with Philco for an provement study of the JPL S-band transponder. The experimental data from s study will be available for comparison with theoretical predictions.

Analysis of Frequency-Multiplexed PM Communication Systems

In frequency-multiplexed PM communication systems, the RF carrier is ph modulated by angle-modulated sine waves or binary-valued signals. Extractors fo the information carried by these signals process the output of a phase-locked-loop receiver. This receiver tracks the instantaneous phase of the carrier component the received signal and coherently demodulates the subcarrier modulation. The objective of this task is to simplify the problem of evaluating this system to that o evaluating the performance of the extractors for each subcarrier channel in obtain ing the required information from the subcarrier signal, distortion, and white gaussian noise. The objective of this analysis is, also, to simplify the problem o evaluating the carrier channel to that of evaluating the performance of a phase-locked-loop receiver in generating a coherent reference for demodulating the sub-carrier channels from the carrier component of the received signal, distortion, a white gaussian noise.

The objective will be satisfied by two means: (1) demonstrating that over th frequency band of interest the power spectral density of the gaussian noise at the receiver output is the same as that of the gaussian noise at the receiver input, an (2) deriving equations for the amplitudes of the SxS components of the receiver in and output. For each extractor that processes the receiver output to recover the information carried by an angle-modulated sine wave or binary-valued signal, on of the SxS components of the receiver output will be the desired signal. The rema ing SxS components of the receiver output are distortion. In evaluating the performance of the carrier tracking loop, one of the SxS components of the receiver input will be the desired carrier signal.

A Decoding Algorithm for Reed-Muller Codes

In a JPL SPS article[1] it was shown that the existence of a matrix R(m), havi an m-th power, which is the Reed-Muller Code matrix H(m), leads to a useful decoding algorithm for codes whose matrices can be obtained by permuting or co plementing the rows or columns of H(m). In the article, the existence of R(m) wa quoted as a special case of a theorem for which proof was omitted. This analysis proves the existence of R(m) directly.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. Koerner, M. A., "A Decoding Algorithm for Reed-Muller Codes," SPS 37- Vol. IV, pp. 210-212.

2. Boyd, D. W., "Signal to Noise Ratio Monitoring: Calculation of an Importa Probability Density Function," SPS 37-37, Vol. IV, pp. 259-261.

3. Boyd, D. W., "Signal-to-Noise Ratio Monitoring: SNR in the Dynamic AG Output," SPS 37-38, Vol. IV, pp. 202-206.

[1] SPS No. 37-17, Vol. IV, pp. 71-73.

. Boyd, D. W., "Signal-to-Noise Ratio Monitoring: Error Analysis of the Signal-to-Noise Ratio Estimator," SPS 37-39, Vol. IV.

UBLICATIONS ANTICIPATED DURING THE NEXT REPORT PERIOD

None.

HIGH-IMPACT COMMUNICATION SUBSYSTEM TECHNOLOGY

NASA Work Unit 186-68-04-14-55
JPL 384-62801-2-3550

J. L. Adams
M. G. Comuntzis

JECTIVE

The objective of this work unit is to develop the technology necessary to build mmunications equipment capable of surviving high (10, 000 g, 500 fps ΔV) impacts d, further, to achieve such level of technology within typical spacecraft develop-nt constraints of tight schedules, extreme reliability requirements, and low pro-tion. During this study, the work unit will be closely coordinated with the h-impact packaging technology unit.

Past developments in conjunction with lunar capsules and in the JPL high-impact gram have proven that communication equipment can be made extremely rugged h little sacrifice of other qualities. This present effort is intended to provide wledge concerning the ruggedization of equipment, which can be used either as ign data for hard landers or as a margin for trade-offs between ruggedization and ardation systems for the optimum design of any lunar or planetary lander. Such rmation is essential for the proper design of future Mars landers.

OGRESS

During this report period, JPL personnel provided mechanical consultation and formed 59 impact tests in support of the high-impact Traveling Wave Tube elopment being performed by the Watkins-Johnson Company for the JPL Telecom-nications Division under contract JPL 951287. Test items included both helices body circuits.

Phase I of the high-impact crystal development contract, JPL 951080, is essen-ly complete. The chief remaining difficulty seems to be in preventing contami-ion during fabrication. The next phase of the work will be the production of a ber of crystals for life, sterilization, and other performance tests. One of the totype crystals, manufactured by Valpey-Fisher Co., was installed in the S-band istic beacon and impacted in all principal directions at 10, 000 g from 180 fps. greatest frequency shift detected at the crystal (nominal frequency 19. 125 MHz) 18 cps.

Further effort was expended on the ruggedized cavity-backed spiral antenna ing this period. The antenna was re-designed and subjected to impact tests in all cipal directions. It successfully survived tests of 10, 000-g peak amplitude from -impact velocities of 180 fps.

BLICATIONS DURING FY 1966

ers Presented at Meetings and Symposia

Adams, J. L., and Comuntzis, M. G., "High Impact Spacecraft Equipment," 35th Annual Shock and Vibration Symposium, October 27, 1965.

JPL SPS Contributions

1. Adams, J. L., "High Impact Technology," SPS 37-35, Vol. IV, p. 72, August 1, 1965 to September 30, 1965.

2. Adams, J. L., "High Impact Technology," SPS 37-37, Vol. IV, p. 86, December 1, 1965 to January 31, 1966.

JPL Technical Reports

1. Adams, J. L., The JPL High-Impact Program - 1965, TR 32-844, February 1, 1965.

PUBLICATIONS ANTICIPATED DURING THE NEXT REPORT PERIOD

None.

100- TO 500-W ELECTROSTATICALLY FOCUSED AMPLIFIER PHASE I

NASA Work Unit 186-68-04-15-55
JPL 384-66301-2-3360
L. J. Derr

3JECTIVE

The objective of this work unit is to initiate development of an S-Band ariable power) 100- to 500-w Electrostatically Focused Amplifier (ESFA) employ- a hybrid design and a heat radiating collector.

The design will be a scaled-up version of the tube developed under NASA work t 186-68-04-09-55 (20- to 100-w ESFA, JPL Contract No. 951105).

ATUS

Funds for this phase in the amount of $150,000 have been committed from the oject NASA work unit. Development efforts at Eimac on this part will not be author- d until the desirable parameters have been achieved on the 20- to 100-w ESFA.

An additional $120,000 will be needed to complete this phase. FY 1967 funds ler NASA work unit 186-68-04-09-55 will provide $40,000 of this amount.

BLICATIONS DURING FY 1966

None.

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

HIGH-IMPACT SCIENTIFIC INSTRUMENT TECHNOLOGY

NASA Work Unit 186-68-06-01-55
JPL 384-65501-2-3550

J. L. Adams
M. G. Comuntzis

3JECTIVE

The objective of this work unit is to develop the technology necessary to allow building of high (10,000 g, 500 fps ΔV) impact-resistant scientific instruments. is knowledge is necessary for the proper design of any lunar or planetary lander ich as the future Mars landers). If the lander is a "hard" lander, the knowledge design information. If the lander is a "soft" lander, the knowledge is required in der to make trade-offs between equipment ruggedness and retardation system.

OGRESS

This work unit was terminated in February 1966. Before termination, a com- ted gas chromatograph, minus its sample valve that was replaced by a septum for ting purposes, was impacted in all principal directions at a level of 3,000 g from pact velocities of 50 fps. Although the instrument could not be checked as an oper- ng unit, electrical circuit tests and visual mechanical checks could determine no radation. Since all critical components had previously survived test levels in ess of 5,000 g, the instrument could undoubtedly have survived more severe pacts with little or no changes required. However, the effort was halted after pre- inary testing because of the feeling on the part of NASA Headquarters that devel- nent of specific scientific instruments for high impact was premature at this time.

BLICATIONS DURING FY 1966

pers Presented at Meetings and Symposia

Adams, J. L., and Comuntzis, M. G., "High Impact Spacecraft Equipment," 35th Annual Shock and Vibration Symposium, October 27, 1965.

L SPS Contributions

Adams, J. L., "High Impact Technology," SPS 37-35, Vol. IV, p. 72, August 1, 1965 to September 30, 1965.

Adams, J. L., "High Impact Technology," SPS 37-37, Vol. IV, p. 86, December 1, 1965 to January 31, 1966.

L Technical Reports

Adams, J. L., The JPL High-Impact Program - 1965, TR 32-844, February 1, 1966.

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

HIGH-IMPACT BATTERY TECHNOLOGY

NASA Work Unit 186-68-07-01-55
JPL 384-64301-2-3550

J. L. Adams
M. G. Comuntzis

CTIVE

The objective of this work unit is to develop the technology necessary to allow ilding of batteries capable of surviving high (10, 000 g, 500 ft/sec ΔV) impacts ypical spacecraft development constraints (tight schedules, extreme reliability ements, low production). Past developments in conjunction with lunar cap- and in the JPL high-impact program have indicated that batteries can be made nely rugged with little sacrifice of other qualities. This effort is intended to e knowledge concerning the ruggedization of batteries. This knowledge, which used either as design data for hard landers or to allow trade-offs between lization and retardation systems for the optimum design of any lunar or plane- inder, is essential for the proper design of future Mars landers.

RESS

During this report period, a Sonotone cylindrical 3.5 amp-hr heat-sterilizable -cadmium cell was impact tested. The cell was exposed to impacts in three ions (the longitudinal direction with terminals trailing and two orthogonal trans- directions) at levels of 3, 000, 7, 000, and 12, 000 peak g from velocities up to 'sec. The top seal was broken during the last impact at 12, 000 g. However, mance tests before and after testing showed no measurable degradation as a of the impacts.

Several prototype battery cells, developed as a portion of JPL Guidance and ol Division contract 951296 with the Electric Storage Battery Company, were under impact. These cells were physically the same size as the Mariner IV y cells. The first group to be tested consisted of 6 dummy cells. These cells ited three proposed designs fabricated in polysulfone P-1700 and polyphenylene grade 531-801. The dummy cells contained simulated plate packs constructed l shot and Epocast 220927. A void space between the dummy plate pack and the 'er was filled with 40 wt % KOH. These cells were potted with Dow Corning c RTV 881 into a rigid aluminum fixture. They were impacted terminal-end rom velocities ranging from 162 to 170 fps at average g levels between 6460 20 g (corresponding to peaks on the order of 10, 000 g). One polyphenylene cell cracked at the terminal end. This crack was probably caused by voids in ting between cell and fixture. None of the other cases cracked.

The next group of cells to be tested consisted of 10 identical live cells with lphone cases. These cells differed from the Mariner IV cells mainly because presence of structural frameworks in the plates themselves and improved upport techniques. Each cell was tested only once. Five different directions act were examined at two impact magnitudes. The directions were terminals g, terminals trailing, normal to the plane of the plates, and both directions el to the plates and normal to the terminals. The impact levels were approxi- 5, 000-g peak amplitude and approximately 9, 000-g peak amplitude. Voltages ecorded during impact and the cells were checked electrically and then

dissected after impact. Voltages typically dipped 100 mv (out of 1.4 v) at imp recovered in a millisecond, or less. The cells impacted terminals first at 5, and 9,000 g, and the cell impacted at 9,000 g parallel to the plates, normal to terminals, and positive terminal side first, cracked. The other seven surviv no case cracks. No open or short circuits occurred in any of the 10 cells.

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

1. Adams, J. L., and Comuntzis, M. G., "High Impact Spacecraft Equipm 35th Annual Shock and Vibration Symposium, October 27, 1965.

JPL SPS Contributions

1. Adams, J. L., "High Impact Technology," SPS 37-35, Vol. IV, p. 72, August 1, 1965 to September 30, 1965.

JPL Technical Reports

1. Adams, J. L., The JPL High-Impact Program - 1965, TR 32-844 February 1, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

TOUCHDOWN STABILITY STUDY
NASA Work Unit 186-68-09-03-55
JPL 384-63501-2-3500
J. A. Garba

JECTIVE

The objectives of this unit are to conduct a three-dimensional stability study of hree-legged vehicle, and to establish stability boundaries for the Surveyor space-ft. Emphasis is placed on the investigation of possible degradation of the stability ndary by the introduction of three-dimensional parameters.

MPUTER PROGRAM

The Bendix Corporation, Bendix Products Aerospace Division, South Bend, iana, has successfully developed a computer program for the stability study of a ee-legged vehicle landing on a hard surface. The program is currently being used JPL.

ATUS

In preparation of the Surveyor Mission A a unilateral modification was issued JPL on March 25, 1966. The contractor was asked to modify the existing com-er program to do the following:

1. Calculate the lunar slope from the spacecraft touchdown data.
2. Accept a simple analytical soil model such that the penetration of an actual landing could be simulated.

The modified program is being successfully used by JPL in the data reduction he Surveyor Mission A. So far, the Mission A landing has been simulated on a d surface. Excellent agreement has been obtained between flight touchdown data computer prediction. Next, it will be attempted to simulate the estimated pene-ion of the legs into the soil.

Future work will consist of incorporating different analytical soil models to dy the effect of a nonrigid soil on the landing dynamics of Surveyor.

BLICATIONS DURING FY 1966

None.

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

(A final report covering the total effort in this work unit is to be delivered to by the contractor by last of July 1966.)

ENGINEERING MECHANICS STUDIES
NASA Work Unit 186-68-09-04-55
JPL 384-62301-2-3500
J. E. Long

OBJECTIVE

The objectives of the studies performed under this work unit are:

1. To identify new requirements and develop concepts which may provide substantial improvements in a spacecraft performance.

2. To assess the activity within the division to enhance the success of future missions.

3. To support Advanced Technical Studies.

For FY 1966, specific objectives are to develop understanding of "unique" impact attenuators, nonaxisymmetric loading of capsule structures, impact attenuator removal mechanisms, and heat shield-ablation product interactions to ensure that appropriate approaches are utilized on Voyager.

PROGRESS

There was no effort expended on this work unit during the last six months because of lack of manpower. Key personnel were pulled off this effort to be placed on higher-priority programs.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

SPACECRAFT DESIGN TECHNOLOGY

NASA Work Unit 186-68-09-06-55
JPL 384-63801-2-2920
K. H. Fishback
D. Alderson
Dr. P. Gottlieb
R. H. Osborn

BJECTIVE

The objective of this task is to develop insight into the alternative design and chnology approaches for future spacecraft missions and to prepare data on these ternatives, which will serve as background information during subsequent project sign and mission study periods.

'UDY APPROACH

The approach in this study is directed toward extending the functional analysis chnique now in use in system study and system design efforts at JPL. By means of s technique, the objectives of a mission are converted into the functional perfor-ance requirements that must be met by the system. Various combinations of the pos-ble subsystem mechanizations capable of performing these functions are formulated, elding a number of systems potentially capable of carrying out the mission objec-es and illustrating a variety of overall system philosophies. These combinations e then examined for performance level, systems integration problems, probability mission success, state of the art, and relevant parameters.

)RK UNIT PROGRESS

During this report period, effort in this work unit has been concentrated on:

1. Continuation of efforts to develop a "Spacecraft Design Data Information System."

2. Efforts to formulate a basis for contract initiation of a spacecraft system level study for Spacecraft Data Handling and Control Technology.

3. Continuation of effort to develop analytical methods to assess the probability of success for a spacecraft traversing the asteroid belt in missions to the outer planets.

4. A preliminary study to identify possible areas of future study to utilize the Spacecraft Flight Operations Facility to perform final system tests.

5. A preliminary analysis of system requirements to perform an Earth occultation experiment on a Jupiter flyby mission.

SPACECRAFT DESIGN DATA INFORMATION SYSTEM - R. H. Osborn

The objective of this task is to design, develop, and implement a technical information system for space flight project data that could be used as a base for th development of advanced technology. The information system would include space- craft design information for all flight-proven space hardware and projects data. Essential usage objectives envisioned for the system are for the following:

1. Future project studies: Technology design tradeoffs may be evalu- ated on the basis of such data to provide firmer planning for techni approaches to be pursued; further, the system may infer the magn tudes in weight, power, dollars, etc., to be allotted for various technical approaches and, in general, serve as an indicator for pr ject decision making.

2. Surveys and studies relating to prior projects (Lunar Post Apollo, Observatory studies, etc.): The system provides a filtering of the most essential data, allowing greater efficiency in the conduct of such tasks.

3. Development of advanced technology: The system provides a state of-the-art information for flight-worthy hardware, and illustrates design improvements possible through flight analysis.

4. Developing project trends and estimates: The accumulated data p vides the basis for regression analysis.

The technical approach to this task was a progressive study of the total imp of an information system on Project organization and an iterative process in the development of a systems engineering approach to the information system. Initial an in-house prototype information system was designed and developed around the Ranger and Mariner projects. Manpower ramifications forced follow-on efforts t require assistance of contract effort through a competitive industry solicitation. two-phase contracted effort was formulated: the first phase was the design and de opment of a firm information system; and the second phase, primarily, will imple ment the system for approximately 34 projects. The final product, as presently envisioned, will be an eleven volume set of loose leaf binders to be distributed, g erally, within the Laboratory and distributed selectively, as directed by NASA, t NASA centers and prime contractors within existing document-distribution networ The latter distribution and printing costs will probably be borne by NASA (S&T) o national level.

During this reporting period a study contract was placed with the RCA (Astr Electronics Division). The study was completed and resulted in a recommendati implement the information system with a second-phase contract effort. The infor tion system design was extensively refined and firm system specifications were p duced. The ability of a contractor to collect technical data on various space proj was proved by the collection of almost 1,000 selected documents for 34 projects. was determined that the data collection effort is much more effective when accom plished in person at the project location than when accomplished by corresponden methods or inquiries to national documentation centers. The study contract resu in a final report and a typical volume of data sheets for the NIMBUS and TIROS

rojects (Publications During FY 1966, item 2). A comprehensive technical review f the phase 1 effort is presently in the final stages of completion.

Plans for FY 1967 effort on this task include the complete implementation of all 4 spacecraft projects with minor deviations from the information system developed the phase 1 effort. Various approaches to select an appropriate contractor to perrm the phase 2 contract have been studied, including use of non-profit organizaons, research and consulting firms, and the project prime contractors themselves.

PACECRAFT DATA HANDLING, PROCESSING, AND CONTROL STUDY - H. Fishback

The objectives of this study are the application and evaluation of new technology perform the functions of spacecraft and mission data management and control. It the aim of such a study to develop a rationale for the selection of a proper technil approach in meeting new requirements of future projects.

As a basis for the study, a Jupiter Orbiter mission will be defined, and the acecraft system functional requirements will be specified. Although the study will performed in a mission context, the results of the study are expected to be applible, in general, to all future projects. A range of system concepts will be develed, varying in degree of spacecraft autonomy by evaluating (1) mission performance onboard mechanization vs ground control and data reduction, (2) onboard mechaniion feasibility and system design complexity, and (3) project and operational plications of new design philosophy. In addition to implementation studies for ecific Jupiter orbiter requirements, other functions will be defined of a general ure, such as spacecraft self-testing capability, malfunction detection, isolation l correction capability, and special mission functions like real-time approach evision and post-encounter objectives, which all inherently imply a highly autoted system-design capability.

During this report period, an in-house study was initiated to define a Jupiter iter mission, to establish the function requirements of the spacecraft system ign, and to collect other data, such as scientific and engineering data charactercs, to generate the supporting documentation for the study. It was planned to pare a solicitation to industry for the study in the fourth quarter, FY 1966. A liminary statement of work was issued, and $150,000 was committed to perform study. Due to manpower limitations, the effort was curtailed prior to completing necessary in-house effort. The FY 1966 funds were decommitted and recomted to FY 1967, with plans to complete the procurement effort early in the first rter of FY 1967 to obtain the study.

EROID BELT HAZARD MODEL - D. Alderson

The objective of this in-house study is to develop analytic approaches to evaluthe probabilities of success of a spacecraft system penetrating and traversing the roid belt in future outer planet missions and, also, to develop such models to struct computer programs that would be useful in the parametric study of optimal nical approaches.

The technical approach in this study has been to organize four basic factors into nalytic model of the probability of success for spacecraft traversing the asteroid on the basis of current theory and data. The four factors are (1) the asteroid

belt model, (2) the spacecraft penetration criteria, (3) the geometric spacecraft configuration, and (4) the spacecraft trajectory.

During the reporting period, the four factors were integrated into compatible formats and introduced into a general mathematical framework. After applying extensive approximations and assumptions, the framework was implemented into various FORTRAN programs. Spacecraft penetration criteria of Herrmann and Jones (Ref. 1) were adopted, and angular dependence was treated in the manner of Bruce (Ref. 2). These are the same criteria adopted by Volkoff (Ref. 3), but modi fied with a more definite dependence on angle of incidence and as a more realistic function of materials. A new asteroid belt model was designed based on the numbe asteroids (Ref. 4) with statistical corrections from Kuiper et al. (Ref. 5) and a ma dependence cited by Anders (Ref. 6). The new model differs from all previous models, which had been restricted to uniform asteroid distribution densities in sharply limited belts. Figure 1 illustrates the model and compares it with several the earlier models relative to the orbits of Earth, Mars, and Jupiter. The models are all symmetric about the ecliptic plane and independent of ecliptic longitude. T figure illustrates a half cross section of the solar system in the manner of the trad tional contour map. Asteroid orbit densities are plotted as a function of radial dis tance from the Sun and latitude from the ecliptic. The contour lines are labeled w the asteroid orbit densities in expected number of asteroids, with absolute magnitu of 13.6 or less, per cubic AU.

Future effort on this task will document the results and possibly study applic tions of the technique to future mission study efforts.

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1. Herrmann, Walter, and Jones, Arfon H., "Correlation of Hypervelоci Impact Data," Proceedings of the Fifth Symposium on Hypervelocity Impact, Vol. 1, Part 2, pp. 389-438, April 1962.

2. Bruce, E. P., "Review and Analysis of High Velocity Impact Data," Proceedings of the Fifth Symposium on Hypervelocity Impact, Vol. 1, Part 2, pp. 439-474, April 1962.

3. Volkoff, John J., Protection Requirements for the Resistance of Mete oid Penetration Damage of Interplanetary Spacecraft Systems, TR 32- July 1, 1964.

4. Ephemerides of Minor Planets, Institute of Theoretical Astronomy, Leningrad, 1966.

5. Kuiper, G. P., Fujita, Y., Gehrels, T., Groenveld, I., Kent, J., Van Biesbroeck, G., and Van Houten, C. J., "Survey of Asteroids," Astrophysical Journal Supplement Series, Vol. 3, pp. 289-427, December 31, 1957.

6. Anders, Edward, "Fragmentation History of Asteroids," Icarus, Vol pp. 399-408, September 1965.

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PRELIMINARY STUDY TO INVESTIGATE THE FEASIBILITY AND CAPABILITIES F SFOF/SAF INTEGRATED FACILITIES FOR S/C SYSTEM TEST - Dr. P. Gottlieb

A study was undertaken to investigate present system test operational proce-res and to determine the feasibility of using portions of the SFOF integrated into the stem Test Complex of the SAF. The specific objectives of this study were to pre-nt preliminary observations and to define future study areas pertinent to a more finitive establishment of the feasibility of system-test integration of SFOF and SAF. e study also attempted to determine whether there are areas of duplicated effort in se groups and in SPAC and, if so, whether these duplications can be eliminated by ser coordination. We have been primarily concerned with the system tests, which e monitored partly through simulated telemetry. The primary investigation con-rned the SAF on-lab facility with its associated computer equipment, but the results ld apply equally well to off-lab system testing, and to testing at the launch site, hough a microwave or telephone connection to the Laboratory might be required if off-lab facility did not have the appropriate computing equipment.

A cursory investigation was made of current test procedures, implementation, l facilities as a basis for evaluating the use of the Space Flight Operations Facility ng integrated into S/C system test by appropriate RF link, or hard line with the t facility--the primary advantages being to receive direct spacecraft T/M data m simulated flights, to exercise the flight operations personnel and to use the nputer facilities of the SFOF to reduce relevant test data for analysis. The possi-ity and potentiality of using a large central computer facility for system test had n suggested by the Marshall Spaceflight Center Automation Plan for test and ckout of the Saturn Launch vehicles, which has subsequently evolved into the ACE tem.

The results of the study outlined a number of potential problem areas that are ociated with the process of changing the functions of the involved facilities. Under sent testing philosophy, computers are being used in the SAF to monitor and uce relevant test data for analysis, where appropriate; the SFOF is capable of eiving telemetry data from simulated flight essentially for SFOF check-out prior nissions. It is presently planned that the SFOF will be used to monitor the telem-y data during the latter part of Mariner '67 test program. No significant recom-ndations were made for future study as a result of this investigation. However, it noted that a continuation of the present improvement in coordination between SAF SFOF could provide more efficiency of overall operation. Such coordination ld facilitate the "semi-automatic" recording and reducing of simulated telemetry a and, also, would eliminate some duplication of effort involved in writing sepa-e programs for SAF and SFOF monitoring simulated flight and actual flight metry.

IMATION OF THE CHANGES OF THE S-BAND SIGNAL FROM A SPACECRAFT AN EARTH OCCULTATION JUPITER FLYBY TRAJECTORY - Dr. P. Gottlieb

The objectives of this task was to assess the system capability required to per-n an Earth occultation experiment in a Jupiter Flyby mission which is the subject urrent future mission studies. For the most part, minimum system concepts of

interest for first missions are limited data rate systems, which preclude an occultation experiment. A quantitative assessment of the requirement was needed evaluate alternate system approaches.

An occultation provides a reliable means to measure remotely the scale heig of a planetary atmosphere. In order to estimate the scientific usefulness of such a experiment, and in order to estimate the engineering requirements imposed on spa craft design by such an experiment, we have performed numerical calculations to predict the changes in an S-band signal propagating through varying thicknesses of neutral Jupiter atmosphere.

These calculations were performed for various atmospheric models with var ous values of the significant parameters, since our present knowledge of the Jupit atmosphere is rather inexact. The models were all taken to consist primarily of helium and hydrogen in a fixed ratio throughout the atmosphere. The helium percentage for the various models ranged from 100% to 50%. The temperature values ranged from 105 to 145°K. The scale height values ranged from 8 to 12 km, and pressure at the cloud top level was taken to be 1 and 3 Earth atmospheres (no sign would be expected to propagate through the very dense atmosphere below the cloud top level).

The results of the calculations show that the S-band signal will experience d pler rates as large as 620 Hz for all of the atmospheric models used. The signal attenuation due to atmospheric refraction will vary according to the atmospheric model used, and for the models used in this calculation the maximum attenuations ranged from 23 to 31 db. These results suggest that rather large signal strengths will be required. The results of these calculations are presented in much greate detail as part of an internal engineering document.

For a more detailed estimation of scientific results, the effects of the ionosphere would need to be considered; however, for preliminary system design requirements the present analysis suffices.

PUBLICATIONS DURING FY 1966

Contractor Reports, Interim and Final

1. Rosenberg, L., Morton, R., and Morgan, R., "Spacecraft Design Data Information System Final Report," RCA Astro-Electronics Division, AED R-2946, April 15, 1966, JPL Contract No. 951335.

2. Rosenberg, L., Morton, R., and Morgan, R., "Typical Volume I of Space Design Data Information System" (NIMBUS AND TIROS), RCA Astro-Electr Division, April 1966, JPL Contract No. 951335.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

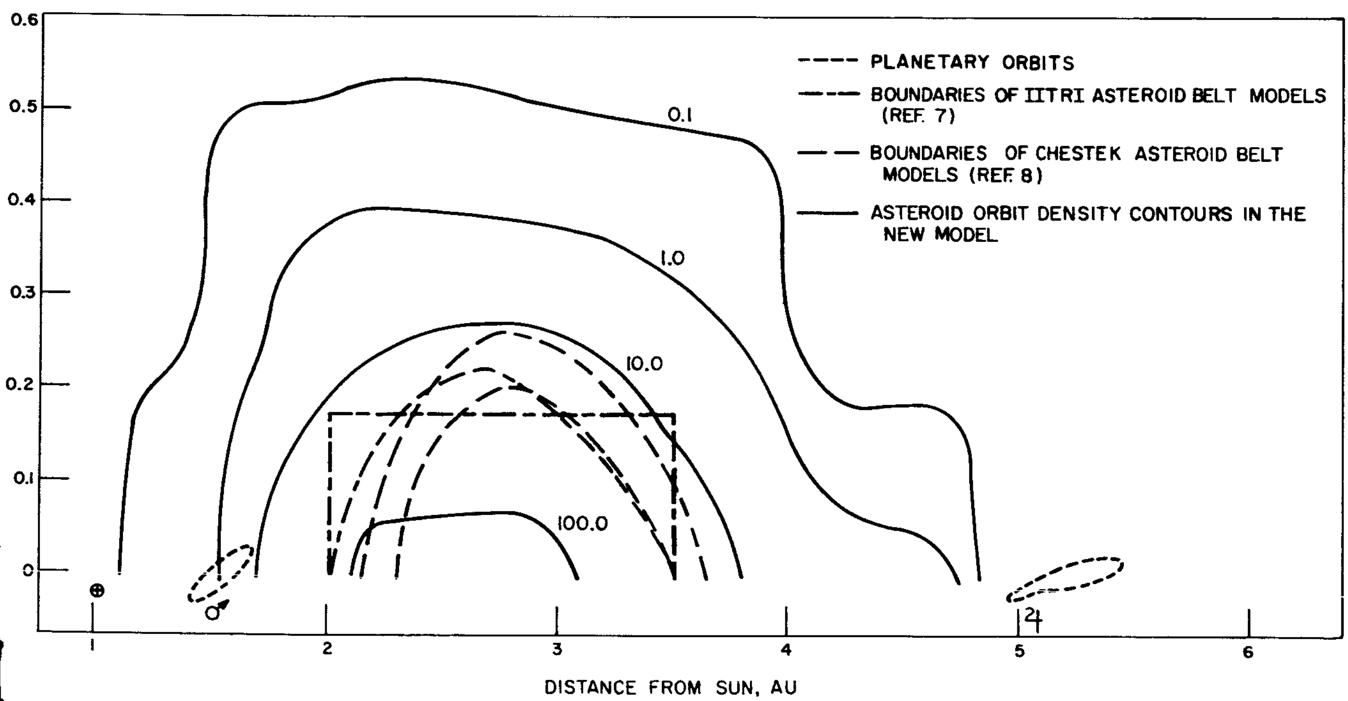


Fig. 1. Asteroid belt models relative to Earth, Mercury, and Jupiter orbits

HIGH-IMPACT MECHANICAL TECHNOLOGY

NASA Work Unit 186-68-10-03-55
JPL 384-65601-2-3550

J. L. Adams
M. G. Comuntzis

JECTIVE

The objective of this work unit is to develop the technology necessary to allow building of mechanical spacecraft equipment capable of surviving high (10,000 g,) fps ΔV) impacts. Lunar and planetary landers (such as future Mars landers) will tain mechanical equipment in instruments, erection systems, recorders, and uators. In order to properly design such landers it is necessary to have know- ge concerning the penalties paid for ruggedization. This knowledge becomes ign knowledge for a hard lander. It becomes trade-off knowledge for a soft lander. ny case it contributes to overall equipment ruggedness. This effort will provide h knowledge.

OGRESS

Figure 1 shows a ruggedized turbine capable of operation from a hot-gas rce. Like previous turbines developed in this work unit, the rotating mass ne 41 alloy, 6-0z weight) is supported in spring-mounted bearings so that major act loads are absorbed by bottoming between the rotating mass and the housing, ner than by the rotating element bearings. This turbine has been impacted at 000 g from 170 ft/sec in the axial and radial directions while operating at 60,000 n. Negligible bearing damage occurred, and damage to the turbine and housing small.

Figure 2 is a layout of a prototype impact-resistant tape transport which is g developed in order to examine problems involved with more complex motor- en mechanisms. This tape transport relies heavily on the soft-mounted bearing roach successfully used on electric motors and turbines such as that shown in 1. Figure 3 is an exploded view of the motor for the tape transport. It is a gedized Gaylord Rives Model B344 size 13, 400-Hz synchronous high-torque or which has been modified to incorporate spring-mounted bearings. The proto- transport will be belt-driven and capable of handling 1-in. tape at a speed of n./sec. It is not intended for any special application, but rather as a vehicle for her study of the technology associated with developing mechanisms capable of standing high impacts.

A small gas generator for use with hydrazine was developed and tested in order nvestigate problems associated with subjecting a catalyst (Shell Development Co. lyst 405) to the impact environment. The generator, holding approximately 6 ns of catalyst, was impacted at 10,000 g from a velocity of 180 fps. The gen- or was operated before and after--but not during--impact, and no performance adation could be measured. This effort is being performed in cooperation with onnel of the JPL Propulsion Division, who are interested in the problems asso- ed with ruggedization of turbine-driven power sources. To date, some experi- has been accumulated not only with turbines and gas generators but, also, with sure vessels and pressure regulators in the impact environment.

A one-dimensional wave propagation experiment has been built and is being used in order to become more familiar with wave phenomena. Wave propagation theory has seldom been used in the JPL high-impact program because of the comp geometries of test specimens and developmental hardware. It is potentially valua since it explains phenomena that occur in distributed media which cannot be explai by other means. Unfortunately, the direction of most wave propagation experimen tation seems to be toward clean and carefully controlled experiments in order to prove pure and rigorous theory. For purposes of design, it is presently more important to gain an empirical feel for wave behavior in more complex geometries The present experimental program at JPL is, therefore, to measure wave behavi in complex geometries and try to explain it by some combination of intuition, emp cism, and theory. Wave phenomena have been observed in several tests of mecan hardware under impact. The intent is to be able to understand such phenomena w enough to further refine design criteria.

PUBLICATIONS DURING FY 1966

<u>Papers Presented at Meetings and Symposia</u>

1. Adams, J. L., and Comuntzis, M. G., "High Impact Spacecraft Equipment, 35th Annual Shock and Vibration Symposium, October 27, 1965.

2. Adams, J. L., "High Impact Resistant Mechanisms," 1st Spacecraft Mechanisms Conference, May 19, 1966.

<u>JPL SPS Contributions</u>

1. Adams, J. L., "High Impact Technology," SPS 37-35, Vol. IV, p. 72, August 1, 1965 to September 30, 1965.

2. Adams, J. L., "High Impact Technology," SPS 37-35, Vol. IV, p. 86, December 1, 1965 to January 31, 1966.

<u>JPL Technical Reports</u>

1. Adams, J. L., <u>The JPL High-Impact Program - 1965</u>, TR 32-844, February 1, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

<u>JPL SPS Contributions</u>

1. Adams. J. L., "High Impact Technology," SPS 37-40, Vol. IV, June 1, 19 to July 30, 1966.

Fig. 1. Ruggedized turbine

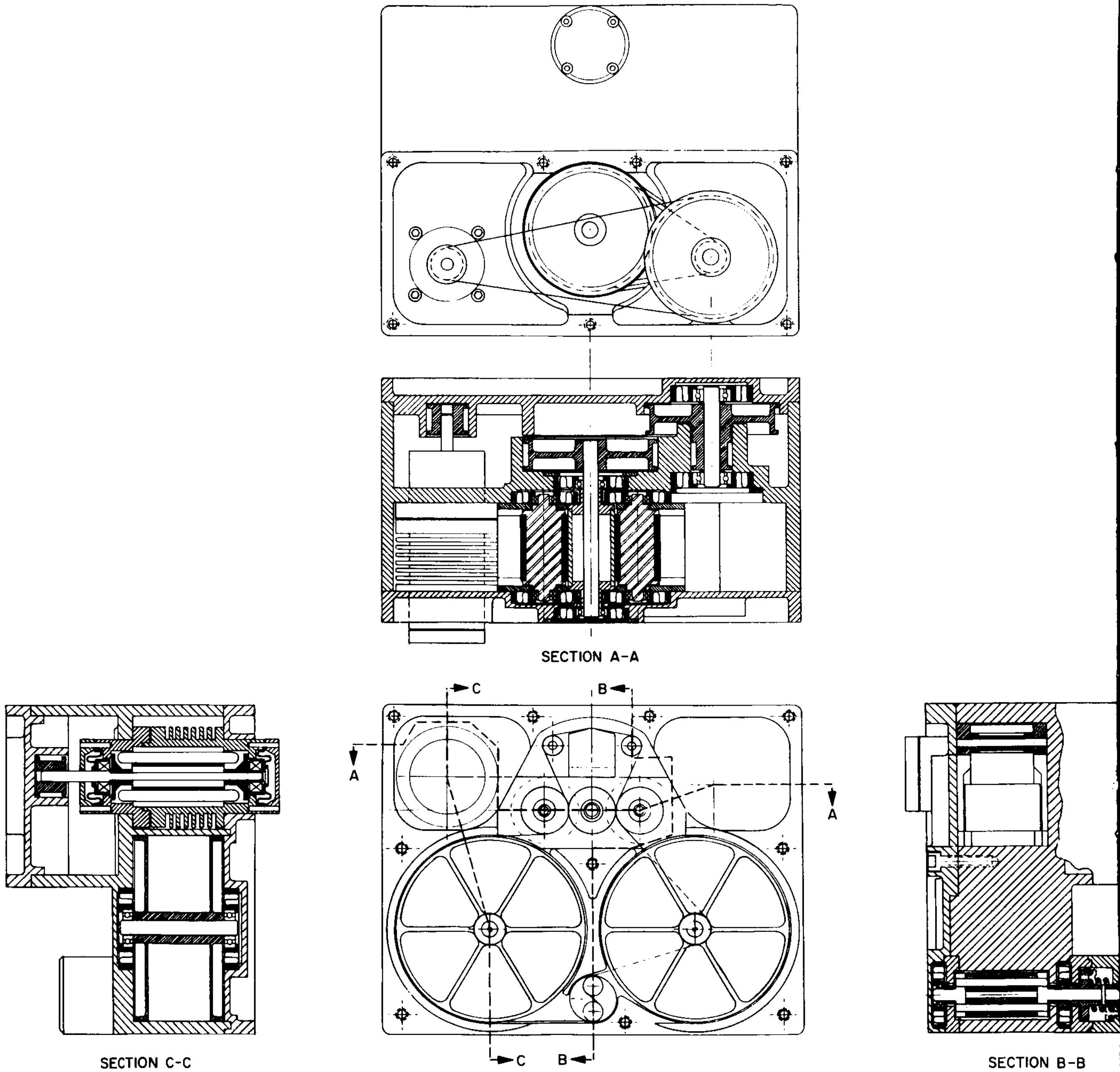


Fig. 2. High-impact tape recorder

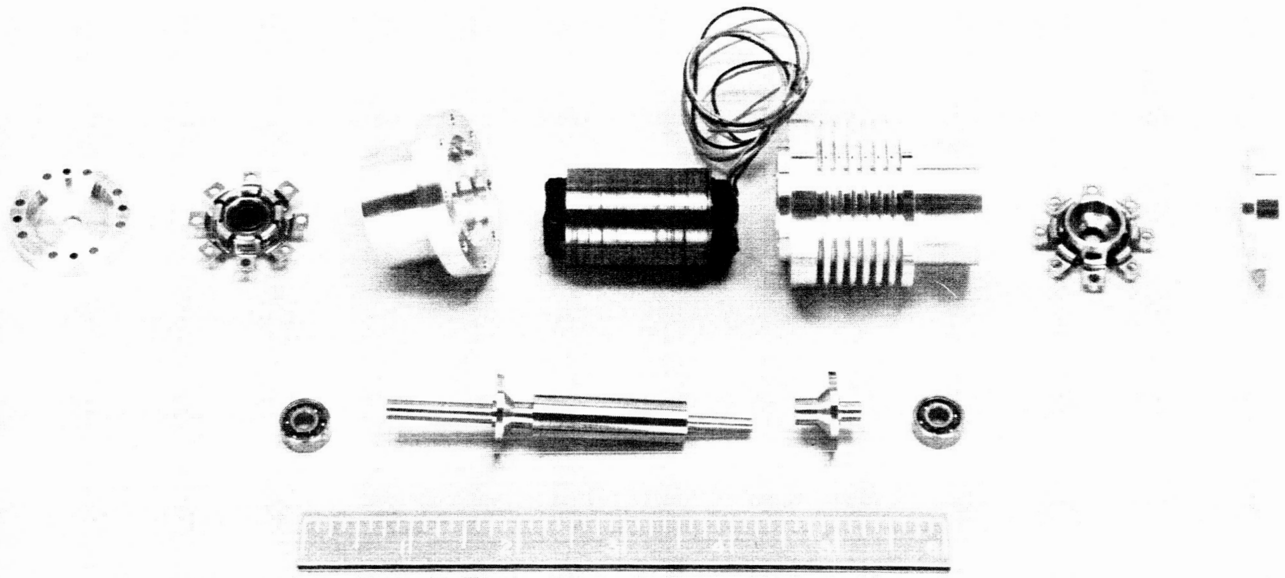


Fig. 3. Ruggedized motor for tape transport

HIGH-IMPACT TESTING
NASA Work Unit 186-68-10-04-55
JPL 384-65701-2-3550

J. L. Adams
M. G. Comuntzis

BJECTIVE

The objective of this work unit is to provide the testing needed in conjunction th the development of high (10,000 g, 500 ft/sec ΔV) impact technology. In order to operly design any lunar or planetary unmanned lander (such as the Mars 1971 nder), it is necessary to understand the response of spacecraft equipment to ıpacts. Hard landers require rugged equipment. The penalties paid for rugged-ation must be known before trade-offs can, therefore, be evaluated. Due to geo-etrical complexity and the unavailability of suitable analytical tools, a great part of s effort must be of an experimental nature. This effort will accomplish such perimentation and develop the necessary test equipment.

OGRESS

During this report period, 201 high-impact tests were performed at JPL. ese tests supported various high-impact development efforts as listed below:

Item	No. of tests
High Impact Communications Subsystem Technology	73
High Impact Scientific Instrument Technology	5
High Impact Battery Technology	26
High Impact Mechanical Technology	2
High Impact Electronic Packaging	30
Miscellaneous	65

The miscellaneous tests included both component investigations and testing hnology investigations. Components tested included squibs, toroids, capacitors, gnets, and vidicon tube parts and subassemblies.

During this report period, fabrication was begun on an improved horizontal-pact testing machine. The old machine is being moved to the JPL environmental t area and will be operated by the JPL facilities division. The move to centralize upgrade the impact test equipment operated by the High-Impact Development oup (the new horizontal machine, the drop tower, and the 3-, 6-, and 22-in.-diam guns) is still underway. The 3- and 6-in. guns are presently being used for work er the sponsorship of the JPL Space Technology Application project, as well as high-impact development work.

One test was performed on an air bag impact limiter, using the 22-in. gun in the configuration shown in the previous report. This was a cooperative effort with the Voyager Development Section. Figure 1 shows the gun and the low pressure chamber in which the impact-limiter was tested. Figure 2 is a view inside the chamber showing the impact-limiter model in the background and a retractable link barricade in the foreground. This barricade is lowered after the impact-limiter ha passed the midway point in the chamber, to prevent the limiter from rebounding an damaging the launching basket. Figure 3 shows the limiter model with the simulat payload mass suspended in the center. The one test was a failure. The model was launched at approximately 175 ft/sec. During acceleration, the bag apparently ruptured in one of its twelve sections and began to lose pressure as it traveled tow the target. This has been attributed to the rapid re-expansion of the rear section a it went from the partially depressed condition of launch (120 g) to the fully expande condition of free flight. The partially deflated limiter was incapable of absorbing t kinetic energy of the payload mass, and the result was a dent in the target block. simultaneous failure of the instrumentation resulted in a loss of camera coverage, it was impossible to determine the exact terminal dynamics of the test item.

Another test limiter has been built and is awaiting test. This limiter is rein forced in the rear section. The launching piston will be decelerated at a slower ra so that the spring-back of the mylar will not be as violent as the limiter leaves the basket. In addition, the limiter will be tested at a lower velocity. The instrument tion has also been re-designed in order to prevent loss of data. The next test shou occur within the month of July 1966.

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

1. Adams, J. L., and Comuntzis, M. G., "High Impact Spacecraft Equipment," 35th Annual Shock and Vibration Symposium, October 27, 1965.

2. Adams, J. L., "High Impact Resistant Mechanisms," 1st Spacecraft Mechanisms Conference, May 19, 1966.

JPL Technical Reports

1. Adams, J. L., The JPL High-Impact Program - 1965, TR 32-844, February 1, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

JPL SPS Contributions

1. Adams, J. L., "High Impact Technology," SPS 37-40, Vol. IV, June 1, 196 to July 30, 1966.

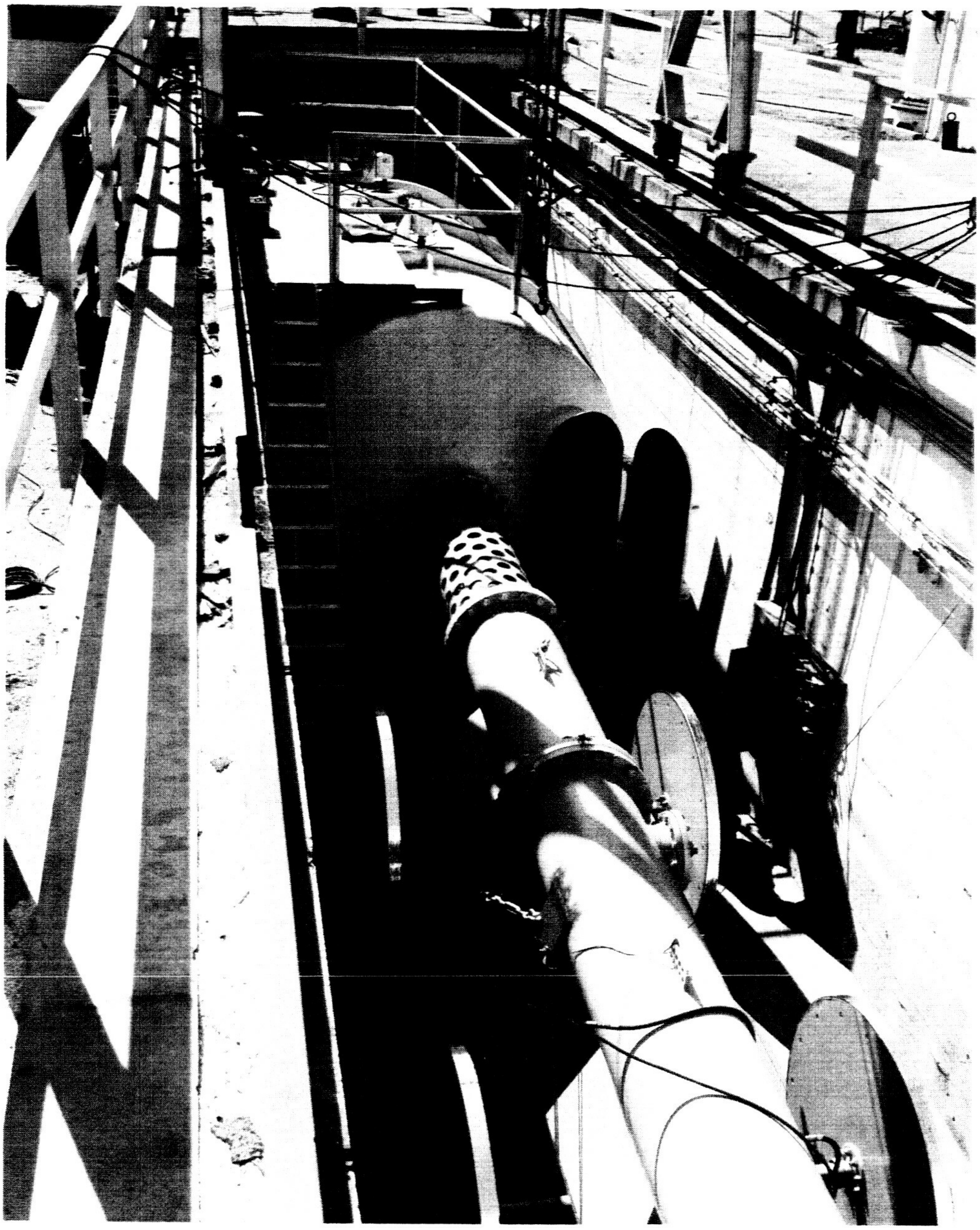


Fig. 1. Gun and low-pressure chamber used for impact-limiter testing

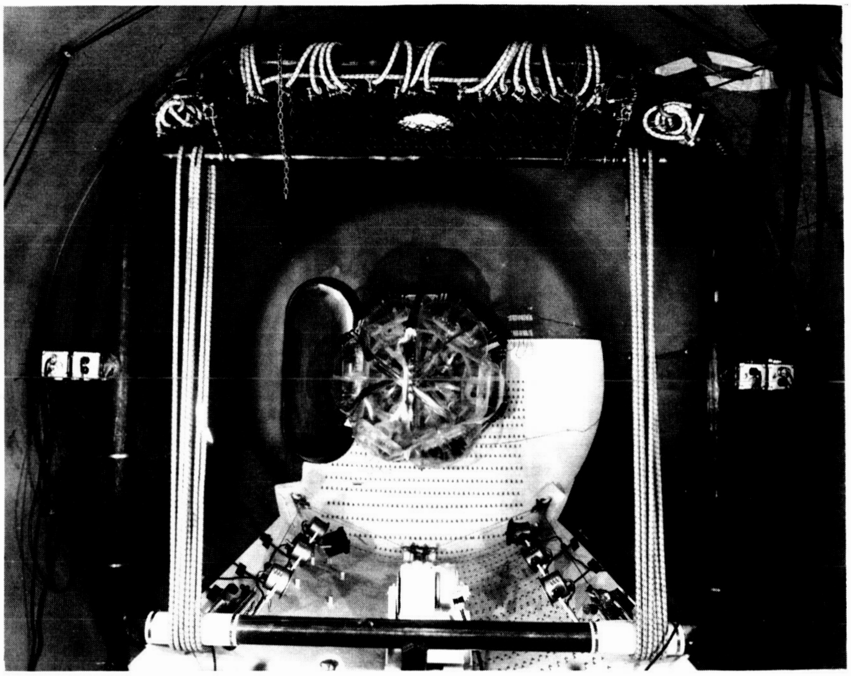


Fig. 2. Inside chamber, showing impact-limiter and link barricade

Fig. 3. Limiter model with simulated payload

HIGH-IMPACT ELECTRONIC EQUIPMENT PACKAGING TECHNOLOGY

NASA Work Unit 186-68-10-06-55
JPL 384-65901-2-3570
Earle R. Bunker, Jr.

JECTIVE

The long-range objective of this work unit is to design and develop spacecraft system and subassembly electronic packaging and cabling technology that will w hard lander capsule equipment to reliably survive high impact (10, 000 g, ft/sec V) with no damage or degradation. The initial objective for FY 1966 was evelop the technology for "typical" subsystem electronic packaging and cabling uirements in support of the Voyager Program, and standard packaging techniques e to be developed and qualified. The objective for FY 1966 has been redirected upport the Surveyor Program, and a preliminary mechanical design of a high-act critical data recorder (CDR) was initiated. The present FY 1966 task objec- is to design and develop the high-impact CDR capsule system configuration, and effort will include packaging and cabling design, connector development, antenna kaging, mechanical integration of the electronic subsystems, and mechanical gration of the impact limiting shell to the electronic system.

DULAR PACKAGING

Further tests were made on embedded, welded cordwood modules of different figurations. As before, these were tested on the "slingshot" test setup for testing edded modules under shear impact loads. Although not yet obtained, because of itations of the test equipment, the nominal goal for high-impact testing is a reli- 10, 000-g design. To date, tests on some components have been made to 15, 000 g no failures. Because of the high compressive forces developed at lower tem-atures, Stycast 1090/11 requires further study.

Methods of packaging transfluxor cores used in core memories, to withstand -impact, were initiated and completed. Such cores are extremely sensitive to hanical strain or shock, so that a successful high-impact packaging technique for e cores could be applied, with success and minimum testing, to other less shock-sitive components. Transformer windings were placed on the core; then, a change ransformer action would indicate a chipped or cracked core. The wound cores e then encapsulated in DC-11, followed by a complete encapsulation in Stycast). This two-step encapsulation procedure prevents the stresses being generated ne Stycast 1090 from being transmitted to the core at low temperatures. Mag-c cores packaged in this manner were tested in three mutually perpendicular axes n 2500 to approximately 20, 000 peak g's in four steps. No failures were erienced.

Successful fabrication of the embedment mold base plate for a high-impact nory core matrix was completed. The matrix assembly will consist of 161 trans-or cores, plus a terminal mother board and all intraconnections in approximately 8 x 2.8 x 0. 150 in. volume. High-impact tests will be run on this assembly n fabrication is completed.

A sub task of developing a suitable interconnection material for welding to molybdenum feed-through terminals on a high-impact vidicon tube was successful concluded. Palladium ribbon (0.010 x 0.030 or 0.020 in.) was chosen because of weldability, solderability, and nonmagnetic properties.

CRITICAL DATA RECORDER

The mechanical design of a high-impact critical data recorder for the Surve spacecraft was continued. The thermal design, configuration, spacecraft integra electronic packaging, and cabling work were done under this work unit. This wo culminated in a JPL internal document in April 1966 entitled, "Critical Data Recorder, Preliminary Design". This report includes a preliminary design of th critical data recorder which was to collect and transmit data associated with a Surveyor landing. The mission objectives, design constraints, and functional sp fications are given with the appendix, which includes the rationale and all availab background material to support the preliminary design phase. Figure 1 (J419074 shows the configuration of the CDR, and Fig. 2, the battery and transmitter secti mock-up. Work on the critical data recorder for the Surveyor spacecraft has be concluded, further work on high-impact packaging techniques will be for general applications, rather than for one specific spacecraft.

Testing of OSM miniature coaxial connectors resulted in some mechanical degradation at 10,000 g. Evaluation of connectors of this type indicated that the was the best choice for the CDR system; therefore, the OSM was mechanically re signed to eliminate potential failure modes. New connector parts were fabricate and the test coax assembly reassembled with JPL designed parts. No tests of th modified OSM coax assembly have been run using the high-impact tester because higher-priority work.

High-impact tests were made with 50-pin Cinch "D" Type and 25-, 15-, and 9 Cannon "D" Type high-reliability connectors, all with associated cabling. For e test, connectors were mounted in the three mutually perpendicular axes with cab soldered to the terminals so that continuous continuity measurements could be m during the test. Equipment (originally designed to measure relay chatter), whic detects an intermittent open of approximately a microsecond, was used to monito continuity.

The 50-pin connector withstood 2,800 g without degradation. Mechanical degradation occurred at 3750 g due to shell deformation and a momentary open w detected in the connector in the vertical position. At 3920 g, gross mechanical a electrical failures occurred in all three axes. Figure 3 shows the test fixture an the damaged connectors. The high-impact shock is applied to the bottom of the b plate of the test fixture. As would be expected, the smaller the connector the greater resistance to a given shock level.

A 15-pin connector is required for the CDR. Tests of the 15-pin connecto showed no failures at 5,000 g but momentary opens at higher g's. No mechanica failures occurred at 10,000 g.

The main mode of mechanical failure, and the probable consequence of the intermittent open circuit was the weakness of the brass shells used in the connec

body. Connectors with stainless steel rather than brass shells have been obtained to test under the same conditions to determine if this mode of failure corrected.

Based on the available manpower, the following work will be performed in FY 1967 in high-impact testing. The "D" Type connectors with the stainless steel shells will be tested in a similar manner to the test previously performed. The modes of failure, if any, will be determined. The miniature coaxial cable connectors which have been modified to increase the resistance to high-impact shock will also be tested. High-impact tests of the transfluxor core matrix will be performed. Tests of other components which are sensitive to high-impact shock will be investigated and other components that are likely to be most sensitive to shock will be tested further as time and personnel allow.

TANTALUM CAPACITOR HIGH-IMPACT TESTS

Four GE 130-μf and four 225-μf capacitors were installed in separate high mpact chassis. Two of each type of capacitors had undergone the sterilization ycles, while the remaining two had not.

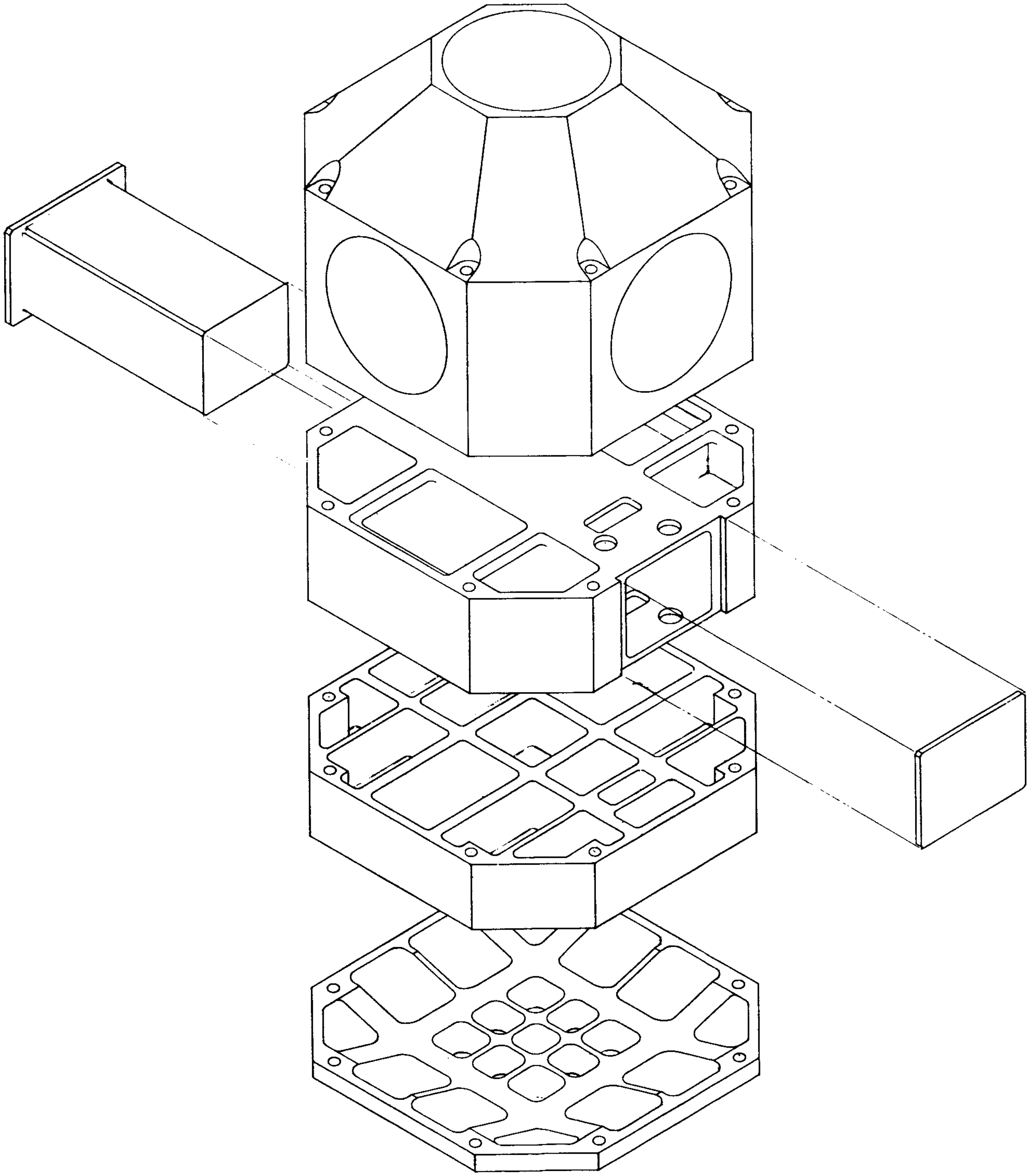
Although the sample size is very small, apparently the sterilization cycles did ot degrade the capacitors, as failures appeared to be random in sterilized and nsterilized units. It was found that the 225 type had the lowest shock tolerance and reatest failure rate. It was also interesting to note that the 130 capacitor survived hock of 5600 g in a plane normal to the major axis of the capacitor, but had 100% ilures when subjected to a lesser shock of 5000 g in a plane parallel with the major xis.

UBLICATIONS DURING FY 1966

None.

JBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.



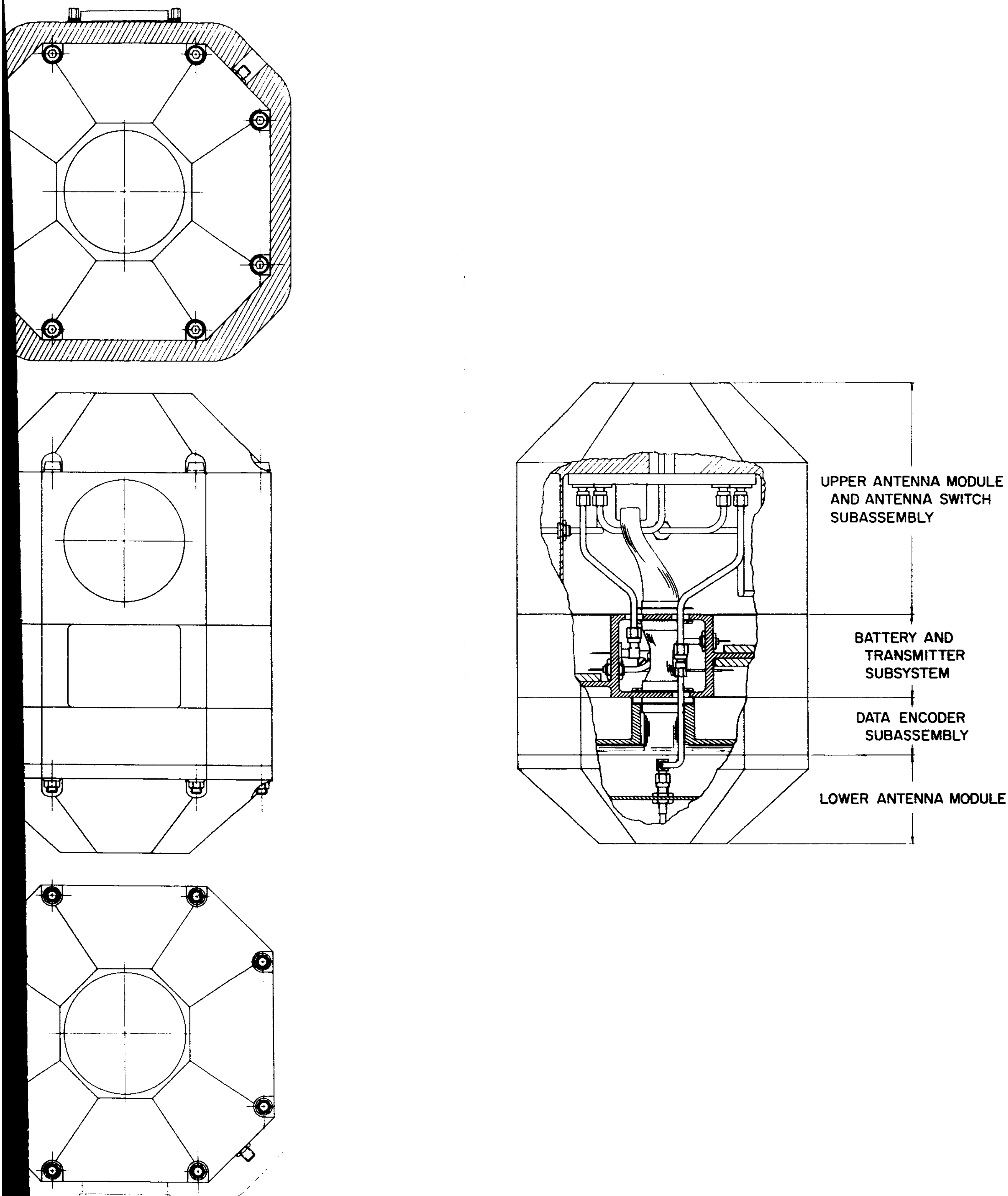


Fig. 1. Configuration of critical data recorder

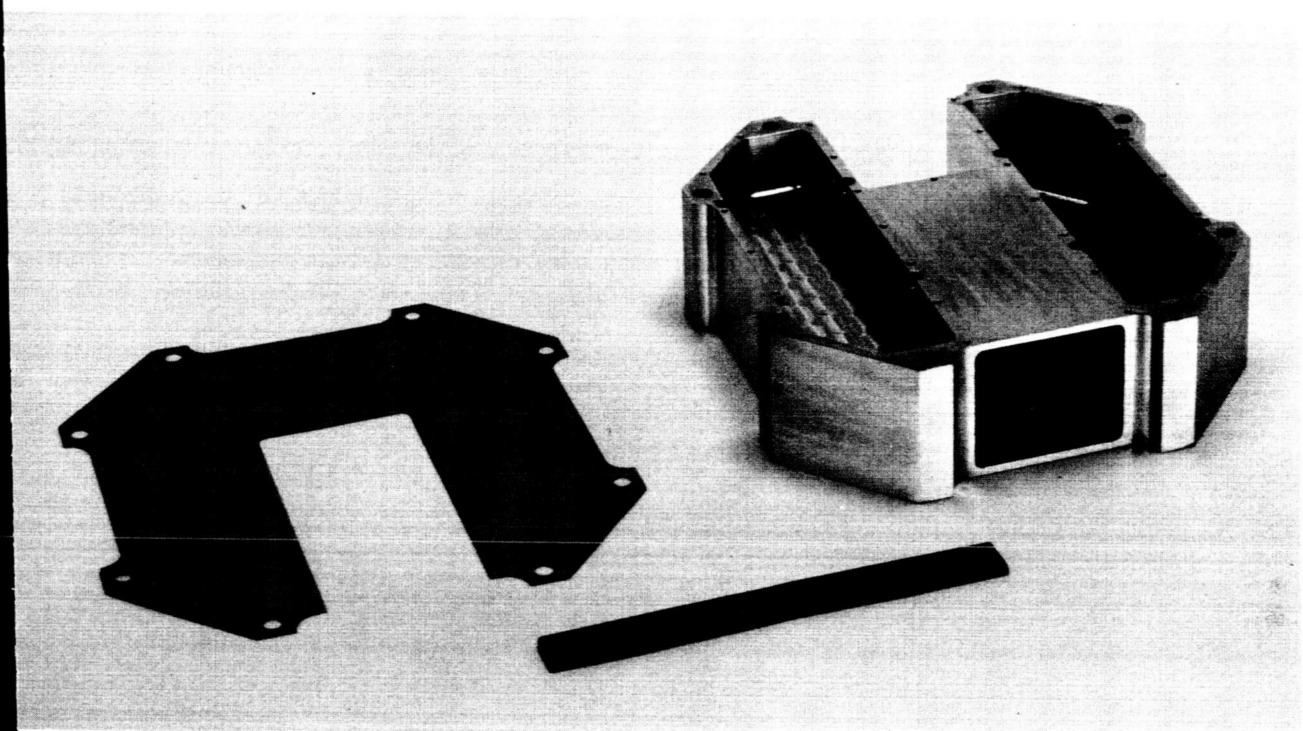


Fig. 2. EDR battery and transmitter section mock-up

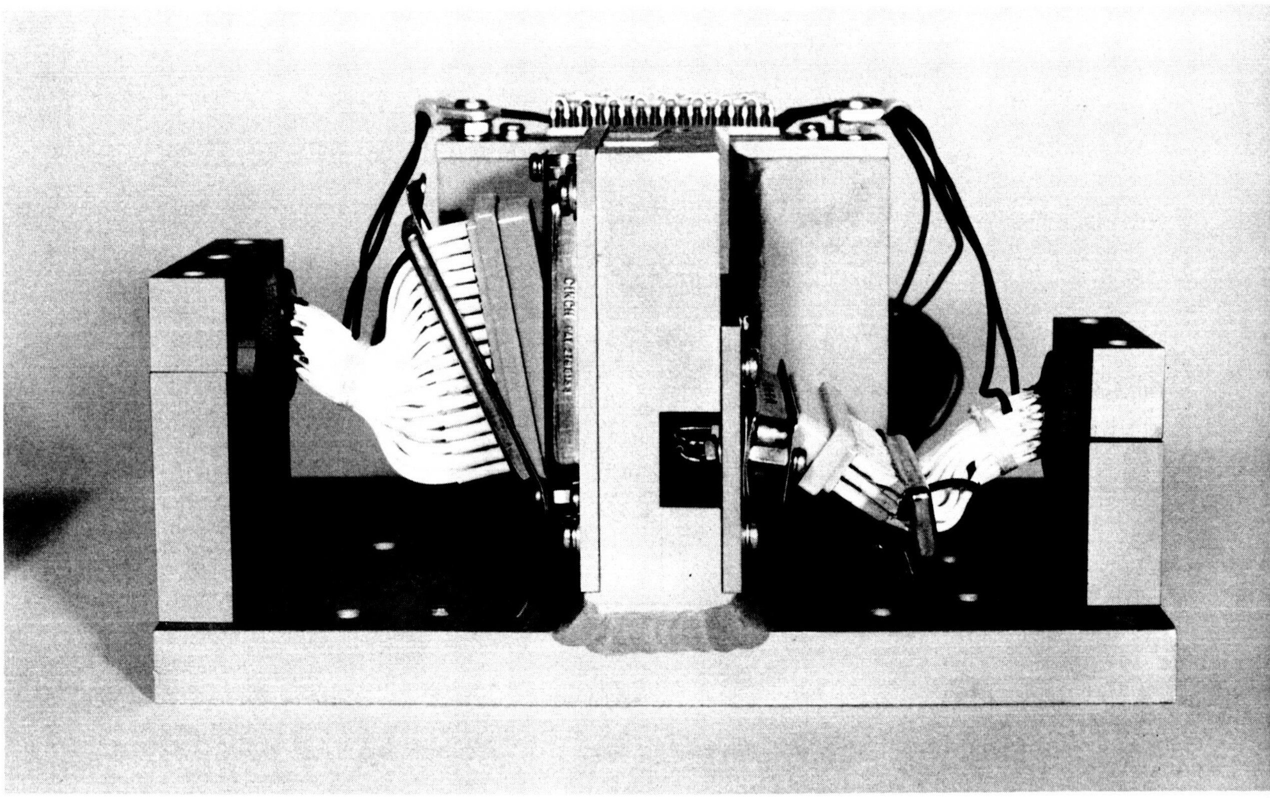


Fig. 3. 60-pin type D connectors after 3920-g shock

HIGH-IMPACT DEMONSTRATION LANDING PAYLOAD

NASA Work Unit 186-68-10-07-55
JPL 384-66201-2-3550

J. L. Adams
M. G. Comuntzis

OBJECTIVE

To develop the technology necessary to allow the building of high (10,000 g, 500 ft/sec ΔV) impact resistant capsule payload and diagnostic package systems. Mechanical and electrical hardware interfaces will be investigated under high impacts. This knowledge is necessary for the proper design of any lunar or planetary lander (such as future Mars landers). If the lander is a "hard" lander, the knowledge is required in order to make trade-offs between equipment ruggedness and retardation system. The function of this effort will be to investigate items of a complex and cross-discipline nature. This work unit will not only produce knowledge, but also uncover problems and help orient the JPL high impact program.

PROGRESS

Effort on this work unit was halted at the completion of the preliminary design on the critical data recorder system for Surveyor. The work during this report period consisted mainly of writing the final report on the preliminary design. The design itself was discussed briefly in the previous semiannual review document under this task number.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING THE NEXT REPORT PERIOD

None.

MODULAR WELDED PACKAGING ADVANCED DEVELOPMENT

NASA Work Unit 186-68-10-09-55
JPL 384-66601-2-3570

Earle R. Bunker, Jr.

JECTIVE

The objectives of this task are to design and develop an optimized, mechanically egrated nonmagnetic, welded-matrix configuration for advanced spacecraft sysns, based on the recently developed gamma ray spectrometer pulse-height anaer welded-matrix design, and to complete a detailed thermal study of welded rdwood modular assemblies.

LDED-MATRIX SUBASSEMBLY DEVELOPMENT

The welded-matrix modular interconnect concept previously reported was to vide a design technique to interconnect welded modules with a welding process ther than soldering) and yet provide a module replacement capability without radation of hardware, as may occur in an etched circuit board with solder connecs. This matrix provided an interconnect assembly of all conductors in predetered locations and, in addition, offered other benefits as compared with the ventional wire harness interconnect technique.

The degree of complexity of the welded-wire matrix interconnections required r layers of conductors, which at first did not appear to be too difficult to assem. Further work in fabrication of these interconnections, including the replacent of modules, has caused some difficulty, in that an excessive amount of manual terity was required of the personnel doing the welding of the connections. The blems are not insurmountable, but it was decided to defer the development of the ded-wire matrix system in favor of the JPL "Wirecon" concept, originally develd for Voyager.

"Wirecon," which is a contraction of the words "wire connected," is a method nterconnecting modules by soldering insulated stranded wires directly to the dule. This is in contrast to other modules systems that use welded-wire matrixes, tilayer printed wiring boards, or separate terminal boards as the interconnection lia and support. To better meet the conditions imposed by spacecraft requirets, wirecon provides a change capability, design flexibility, arrangement free-, ease of wiring, and volumetric efficiency--a combination of qualities not vided by other systems mentioned above. Although this design was developed g modules with welded interconnections, other module designs can be accommoed. The wirecon module used for mounted discrete components and the stick lules, using magnet wire for interconnections for mounting flat packs and some ll discrete components, are compatible with each other. Interconnection to both obtained by wire cable systems. The proposed packaging of the breadboard e-height analyzer will employ both types of modules.

Integration of the welded module, output leads, terminals, and mounting into a le mechanical device were achieved by using a transfer molded header in the ule design. Individual terminals and their associated module leads were designed e one piece and were incorporated as an integral part of the molded header. Fig- 1 shows the 28-pin module header. The terminal ends and leads were placed in

the header so that the terminals have sufficient height to protrude through the structural support to allow wiring on the side opposite from the modules. With this configuration, space was provided for wiring while permitting modules to be placed close to each other, and still access to either side could be maintained. A 24-pin header is also available. The terminal material consists of gold-plated Alloy 90 (11% nickel, 89% copper) which provides a nonmagnetic welding material. The car- rier strip opposite the header holds the module leads in position to facilitate handli during molding and shipping.

Figure 2 shows the wirecon mock-up, wiring side, while Fig. 3 shows the wirecon mock-up on the module side. Because the interconnection wires are on th opposite side, the modules can be placed adjacent to each other, as shown, and stil facilitate a module replacement in late stages of fabrication. It may be hybridized with other systems or used for bread boarding. Standard dimensions allow a singl mounting pattern, plus growth of the modules in height. The orientation of the com ponents allows freedom of design for their arrangement, not dictated by output lead position requirements, and also allows the standardization of the header dimension When compared with welded-wire matrixes and multilayer printed wiring board, wirecon significantly reduces the number of joints in the system, thereby tending t increase the reliability of the system.

Weld schedules and techniques for various types of ribbon materials used in fabrication of the matrix modules and the wirecon modules were investigated. A I Mark II interconnect matrix was fabricated with 0.010 x 0.020 nickel ribbon to eva ate the problems and workmanship skill required in welding with the smaller ribbo rather than the standard 0.030 type. Considerable difficulty was experienced in working with the smaller ribbon, and the fabrication took about three times as lon as required for previous units assembled with the wider ribbon. No particular dif culty was encountered in welding electronic component leads to the gold-plated Alloy 90 leads used in the wirecon modules.

Another project that employs the wirecon module and the stick module appro to the modular welded packaging is the OGO-E plasma probe.

Process work to determine the handling properties of a JPL formulated, lov density embedment compound, which would be a lower density substitute for Styca 1090, was completed. This system, consisting of Epon 815/A with Eccospheres S filler, demonstrated good adhesive characteristics, which is desirable for this application.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

Papers to be Presented at Meetings or Symposia

1. Rhodes, F. L., "Wirecon - A Wire-Connected Module System," Seventh International Electronic Circuit Packaging Symposium, August 1966.

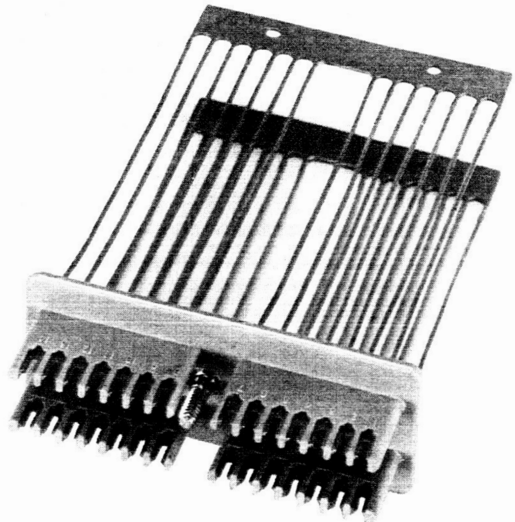


Fig. 1. 28-terminal wirecon header

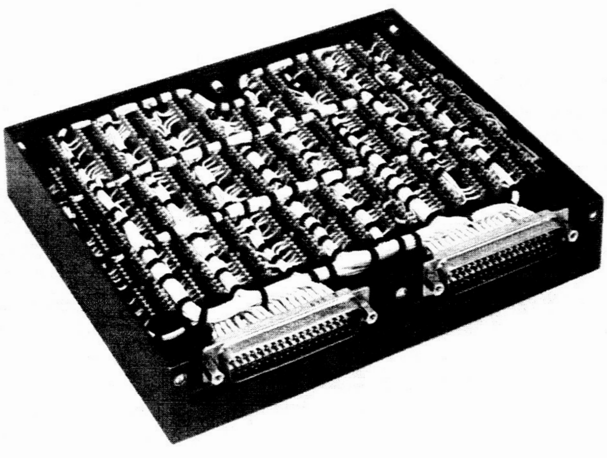


Fig. 2. Wirecon mockup, wiring side

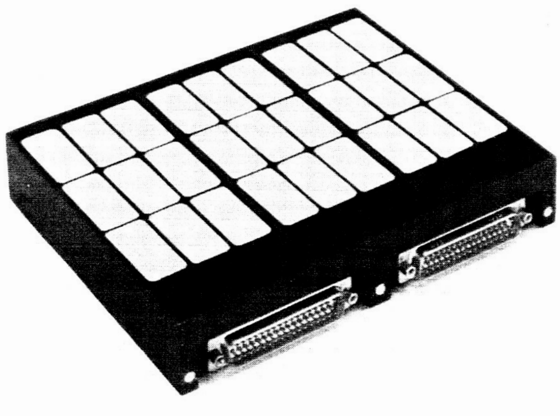


Fig. 3. Wirecon mockup, module side

PLANETARY ENTRY AERODYNAMIC DECELERATION

NASA Work Unit 186-68-13-01-55
JPL 384-62501-2-3530

J. M. Brayshaw
J. W. Stuart

)BJECTIVE

The objectives of this work unit during the second half of FY 1966 were (1) to ontinue technical direction of a contracted study on expandable supersonic terminal ecelerators, (2) to proceed with a plan to award a contract to study parachutes for ransonic deployment, and (3) to complete the contracted study on decelerator- nitiation sensing systems.

:XPANDABLE SUPERSONIC TERMINAL DECELERATORS

The current contract with the Goodyear Aerospace Corporation has the following eneral objectives:

1. Determine the most effective applications of balloon type or expandable vehicle type structures as supersonic Mars atmospheric-entry first-stage decelerators.

2. Study the design problems involved and optimize the weights and packaging required to achieve second stage deployment conditions.

3. Recommend the type having the best combination of drag/weight efficiency, reliability, stability, etc.

oth direct and orbital entries are being considered, with entry ballistic coefficients nging from 0.25 to 0.50 slugs/ft^2. This expandable decelerator would slow the tire entry weight of an entry capsule to second (landing) stage deployment velocity.

Performance ranges being considered are:

Deployment Mach number	2 to 5
Target Mach number	0.7 to 1.5
Target altitude	10-, 20-, and 30,000 ft

The study is approximately at its midpoint. Completion is expected early in vember 1966. One significant result at this point is that a configuration with an lated structure attached to the payload is more efficient than a configuration utiliz- g a trailing balloon.

RACHUTES FOR TRANSONIC DEPLOYMENT

Following the delay mentioned in the previous semiannual report (JPL TM -272), a Request for Proposal was issued in May 1966. Evaluation of four propos- s is currently in progress. Principal objectives of this study are:

1. Analysis to determine best kinds of parachute system(s) for Mars landing application.

2. Fabrication and ground test of model(s) of selected type(s).

3. Preparation of plans for a complete development program.

DECELERATOR-INITIATION SENSING SYSTEMS

During the second half of FY 1966, the main effort in the area has been the directing of a contract with Northrop-Ventura to study decelerator-initiation and specify a mutually satisfactory sensing system.

Northrop-Ventura (NV) surveyed the field for various concepts for sensors and sensing systems. From the 90, or so, concepts collected, about 30 were selected a having potential feasibility. By applying a preliminary performance analysis for orbital and hyperbolic entries of a typical Voyager capsule, the number of systems was reduced to 8 feasible systems.

Three of these systems--Acceleration to Pressure Ratio, Acceleration Function, and Acceleration (each with a separate Pressure backup)--were selected as candidates for complete analysis of mechanization, errors, and reliability. The flight conditions were restricted to an orbital entry and transonic initiation of the decelerator (Mach No. = 1). The marginally superior, Pressure to Acceleration Ratio Primary System with a Pressure Secondary System has been selected for the preliminary engineering specification of the final phase of the contract. This system was selected among the substantially comparable three, because it afforded the most direct indication of Mach number and the broadest capabilities for possible later transfer to one of the other systems. The study is complete, except for the final report.

PUBLICATIONS DURING FY 1966

Contractor Publications

1. Mickey, Fred, "A Study on Sensor Systems for Initiating Parachute Deployment for a Mars Entry Vehicle," Northrop Corp., Ventura Div., NVR-4062, June 1966, JPL Contract 951174 (NV Project 6037).

2. "Monthly Progress Report No. 3, 10 February 1966-10 March 1966," NVT 166-38, 10 March 1966, JPL Contract 951174 (NV Project 6037).

3. Monthly Progress Report No. 4, 10 March-25 April 1966, NVT/66-51, JPL Contract 951174 (NV Project 6037).

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

SPACECRAFT MATERIALS EVALUATION

NASA Work Unit 186-68-13-03-55
JPL 384-62701-1-3820
J. Moacanin

OBJECTIVE

There are two principal objectives of this work unit: (1) to define materials and design parameters that are relevant for the use of cellular plastics as encapsulants for operation in space environment, at the same time finding materials best suited for proposed applications; and (2) to develop a sterilizable flexible foam to be used as a solid-propellant motor liner for Voyager capsule applications, at the same time evaluating thermoplastic block copolymers as VCM-free sterilizable materials.

PROGRESS

Foam Encapsulants

It was demonstrated that the rate of outgassing of a closed-cell foam placed in vacuum can be calculated from a single diffusion constant D that is directly proportional to the foam density and the gas permeation constant P_e. Values of the latter for a variety of polymer-gas systems are available in the literature. More details are given in the last semiannual report.

The egg-shell idea is being explored. By dipping a foam in a resin, such as an epoxy or polyester, a hard protective shell can be obtained. Such a shell will mechanically protect the foam, and will also greatly reduce the outgassing rates in vacuum, thus suggesting a possible way of maintaining the inner gas pressure in space, above the ionization region, for a period of several years. Preliminary tests indicate a tenfold decrease in the outgassing rate for a coated foam (Fig. 1). As part of this study, the possible use of various foams and foam-eggshell combinations as impact limiters will be also considered.

Attempts to determine pressure changes inside a foam by means of pressure transducers are in progress. If successful, this technique will be useful in determining pressures that are developed during the foam formation, curing, and stresses during temperature cycling.

Previously reported test results on dielectric breakdown in vacuum were inconclusive. Therefore, we have initiated a systematic study of breakdown as function of foam density (Fig. 2). After 6 days under reduced pressure at 80°C, one should expect the loss of approximately 90%--and after 37 days, of 99%--of the blowing gas. The decrease in dielectric strength could be accounted for by the loss of gas, so that the curve after 37 days nearly represents the property of the foam itself, i.e., without gas. The important conclusion is that the foam will provide its own dielectric strength, even when the blowing gas pressure is in the Paschen minimum region. Thus, the minimum strength for the 8 lb/ft^3 should be about 20 kv/in.

The next phase will consist of determinations of time to break at voltages above the voltage of incipient corona, V*, and at various frequencies and temperatures. These experiments should allow correlations to be developed that could be used to calculate the voltage life of a foam for any possible condition of practical interest.

Sterilizable Flexible Foams

Techniques and criteria required to blow a flexible foam have been established. Attempts to develop a satisfactory sterilizable elastomer based on PBAA were not successful. However, using a carboxy-terminated polybutadiene, a formulation was developed that yielded an elastomer whose properties were little affected after 150 h at 140°C.

As a possible alternative to the above material, thermoplastic block copolymers of vinylaromatic and hydrocarbon blocks will be evaluated for these potential uses as sterilizable spacecraft materials. These polymers being internally plasticized do not require low molecular weight additives and, therefore, should be free c VCM. Also, since no chemical cross-linking reactions are required, fabrication problems are greatly reduced.

A visit to the information dissemination center at Wayne State University (CAST) last January resulted in our receiving an extensive bibliography on cellular plastics and familiarization with processing equipment at the University laboratorie

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

Work on diffusion was presented at the following meetings:

1. Canadian High Polymer Forum, Ottawa, September 1965.
2. 2nd Conference on Cellular Plastics, Natick Laboratory, April 1966.
3. Society of Plastics Engineers Meeting, Montreal, Canada, April 1966.
4. Gordon Conference on Cellular Plastics, Crystal Inn, Enumclaw, Wash June 1966.

Publications in the Open Literature

1. E. F. Cuddihy and J. Moacanin, "Diffusion of Gases in Polymeric Foams," J. Cellular Plastics (in press).

JPL SPS Contributions

1. Cuddihy, E. F., and Moacanin, J., "Outgassing Rates in Polymeric Foams," SPS 37-34, Vol. IV, July 31, 1965.
2. Cuddihy, E. F., and Moacanin, J., "Temperature Dependence of Outgassing Rates in Polymeric Foams," SPS 37-35, Vol. IV, October 31, 1965.
3. Cuddihy, E. F., and Moacanin, J., "Polymer Permeation Constants from Diffusion Data on Polymeric Foams," SPS 37-36, Vol. IV, December 31, 19
4. Cuddihy, E. F., and Moacanin, J., "Development of Sterilizable Elastomer Foams," SPS 37-36, Vol. IV, December 31, 1965.

Cuddihy, E. F., and Moacanin, J., "Method for Calculating Outgassing Rates of Rigid Closed-Cell Foams," SPS 37-37, Vol. IV, February 28, 1966.

Cuddihy, E. F., and Moacanin, J., "Studies on Sterilizable Foams," SPS 37-37, Vol. IV, February 28, 1966.

Cuddihy, E. F., and Moacanin, J., "Outgassing Rates from Plastic-Coated Foams," SPS 37-39, Vol. IV (in press).

Farrar, J., and Moacanin, J., "Studies on Voltage Breakdown of Closed-Cell Foams," SPS 37-39, Vol. IV (in press).

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

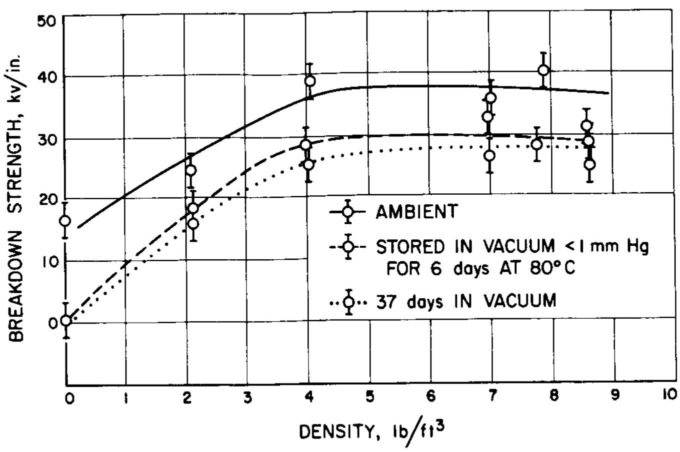


Fig. 1. Outgassing rate for a coated foam

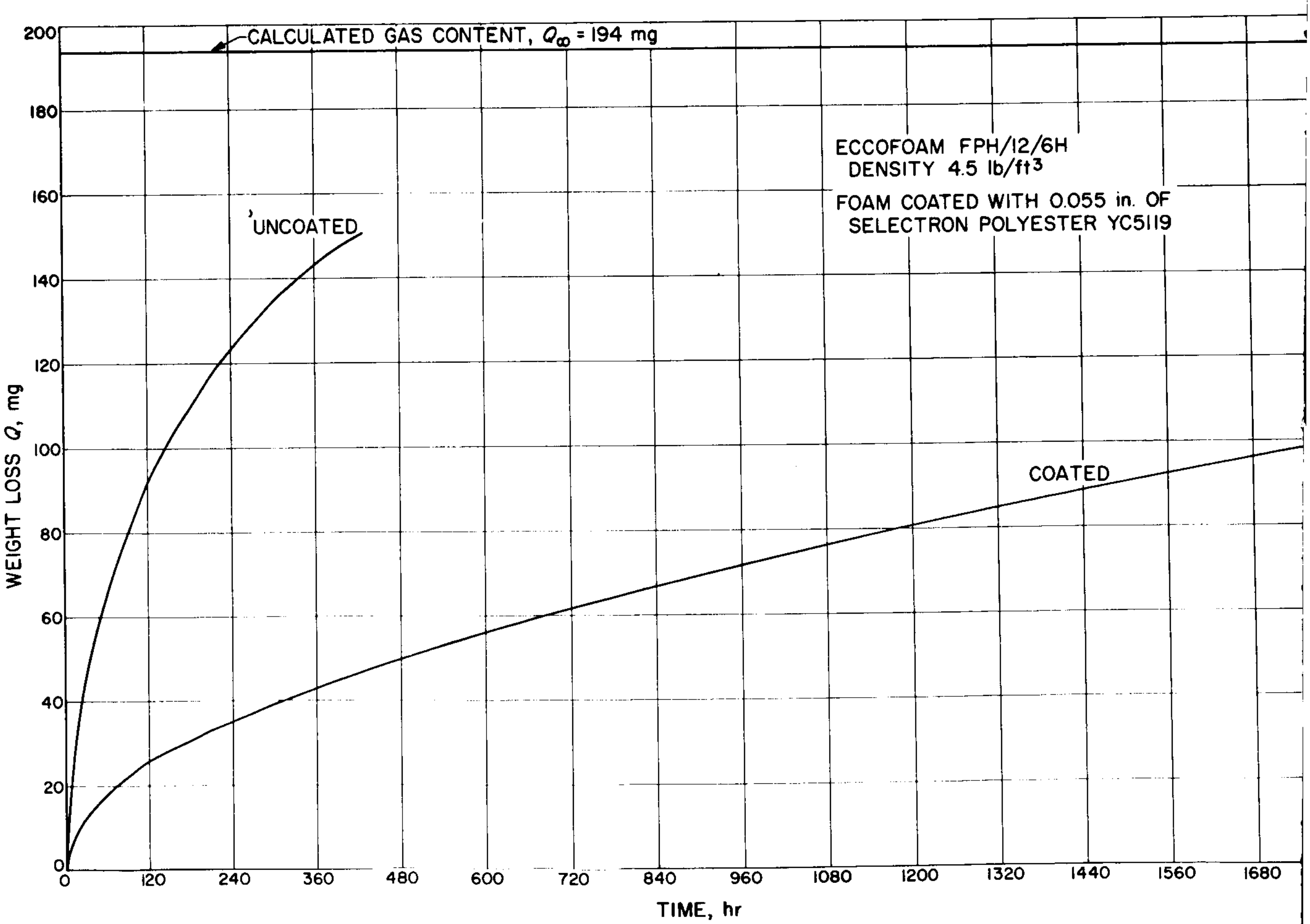


Fig. 2. Vacuum breakdown as a function of foam density

SPACECRAFT RELIABILITY (186-70)
PARTS RELIABILITY-SCREENING METHODOLOGY
NASA Work Unit 186-70-01-04-55
JPL 384-00401-2-3540
W. Bartel

OBJECTIVE

The objectives of screening methodology investigation are to provide improved methods for screening electronic piece parts utilized in spacecraft assemblies. Resulting improved methods will be used for in-house acceptance testing of non-specification controlled parts. Where feasible, such methods will also be incorporated into part-procurement specifications for acceptance testing by the parts manufacturers.

The effort is divided in subtasks for consistency with part types and characteristics being investigated as described in the following paragraphs.

DEVELOPMENT OF MOSFET RELIABILITY TEST AND SCREENING METHODOLOGY

Preliminary in-house studies have been partially completed and have formed the basis for more detailed investigations by subcontractors. The in-house effort has been minimal, due to delays in delivery of required test equipment.

The contracted effort will investigate methods and limits for back-bias testing, as well as effects of 1/F noise and thermal shock. Two procurements have been initiated for performance of the investigations by MOSFET manufacturers. Because MOSFET transistors have unique characteristics and are extremely sensitive to handling, it was determined that MOSFET manufacturers are best qualified to perform this work. These procurements with Fairchild and Siliconix, estimated at $12,000 and $15,000, are currently in process.

AUTOMATIC TRANSISTOR TESTER PROCUREMENT

An automatic transistor testing is required for the preceding subtask, as well as for FY 1967 work unit 186-70-01-08-55. This tester will replace the currently used TACT tester, which is tending to obsolescence and is, also, limited in that it will not adequately handle more advanced transistors such as MOSFET and high-frequency devices. The tester will also be used extensively to support project transistor evaluation.

An evaluation of several testers determined that the Fairchild 500 was the more reliable and versatile. A purchase order for the instrument at a cost of $63,000 was placed in May. It is anticipated that the instrument will be delivered and operational by mid-August.

DEVELOPMENT OF POWER PULSE METHOD OF SCREENING RESISTORS

A screening method has been proposed wherein a short-duration power pulse is applied to the part, with resistance variations being monitored during the pulse period. If feasible, this method will reduce screening time for resistors from two

weeks to a few seconds per unit. Current screening methods include temperature cycles, TC measurements, and burn-in. This effort will demonstrate feasibility by screening parts by both methods and comparing performance in a life test.

A contract (951504) for this effort was let on May 18, 1966 to Mid Continent Laboratories for $49,000. The contractor is procuring test specimens, consisting of 12,000 resistors of various types, and preparing test fixtures. Testing will begin in about one month, with completion scheduled for January 1967.

INVESTIGATION OF TRANSISTOR BACK-BIAS VERSUS POWER LIFE TESTING (FY 1965 FUNDING)

The objective of this effort is to determine the effectiveness of back-bias at elevated temperature in comparison with the currently used power life test. A voltage-temperature matrix test was designed to provide comparative data for the two operating modes, as well as data on the effects of temperature and voltage.

The testing effort is being performed by Preston Scientific, under Contract 951368. The effort is approximately 80% complete; final completion is expected in July. Preliminary results indicate that back-bias is effective in detecting defective parts. The greatest effectiveness appears at maximum-rated voltage and temperature. This is contrary to the postulation by some manufacturers that an optimum back bias screening point exists at a point lower than maximum ratings. A more thorough assessment of results will be made after completion of data processing.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

LONG LIFE STUDIES
NASA Work Unit 186-70-01-05-55
JPL 384-00501-2-3540
L. W. Wright

BJECTIVE

The objectives of this work unit is to examine the behavior patterns of ectronic parts during life test and investigate methods for prediction of part param- er values and part failure rates after as much as 7500 hr operation. These pre- tions shall be based on early life characteristics. A secondary objective is to estigate part failure modes as a function of time and stress.

TIVITIES DURING REPORT PERIOD

btask 1 - Radiation Thermal Vacuum Study (FY 1964, 1965, and 1966 Funding)

The testing and measurement phase of this program has been completed. The al parameter measurements performed at the end of 10,000 hr in a radiation ironment were completed during the first half of this report period. The process- of data has also been completed. All data from this program has been received JPL and has been reduced to computed statistics sheets. During the last half of s report period, work has been primarily directed toward preparation of the final ort. Because of the voluminous amount of data, even in the reduced form of istics, the contract has been modified to allow additional time and funding for npletion of the final report. The total funding for Contract 950458 was increased m $249,020.00 to $249,970.00, and the contract term was extended from April 6 to July 1966.

task 2 - Capacitor Screening Evaluation Test (FY 1964 and 1965 Funding)

Contract 950864 to perform this test per Test Procedure 152.20-01 has been npleted. No catastrophic or parametric failures were observed throughout the re 10,000 hr test program, and little difference was observed between the eened and unscreened parts. This may possibly be attributed to the fact that ing manufacture the parts are briefly subjected to a voltage in excess of that lied during screening. Near the end of test, some parametric degradation had ted to occur in all the parts and it appeared that parametric failure might be erved after 12,000 to 16,000 hr of test.

ask 3 - Diode Screening Evaluation Test (FY 1964 and 1966 Funding)

Progress on Contract 950863 was halted for several months because of a prob- that developed in the control of average forward current. At about the same e 150 diodes were damaged as a result of an excessive reverse voltage. The rol of average forward current has been corrected by a circuit redesign and by acement of some critical components. The life test has now accumulated in ss of 6000 hr and is progressing satisfactorily.

The problems mentioned above resulted in a reduction in scope and an antici- d rebate from the contractor amounting to a credit to JPL of $2,357.00. A

schedule for the test completion has not yet been worked out, but it is expected to b approximately December 1966.

Subtask 4 - Resistor Screening Evaluation Test (FY 1964 and 1966 Funding)

This test program, covered by Contract 950869, has accumulated approximat 9000 hr of test time and is progressing satisfactorily. The test program is expect to be complete by September 1966. A final test report will be available during the latter part of 1966. At the present time, the test samples are still approximately maintaining their initial values.

Subtask 5 - Capacitor Matrix Test (FY 1965 Funding)

This test program, covered by Contract 951125, has been completed and the test contractor has shipped all data and parts to JPL. Progress on the analysis of this data has been halted for several months because of lack of programmer suppo The necessary support has recently been made available and if maintained should allow completion of data analysis and a final report during the second quarter of FY 1967.

Subtask 6 - Diode Comparative Screening Test (FY 1965 Funding)

In October 1965, Preston Scientific of Anaheim, California was awarded fixe price Contract 951367 for $18,646 to perform this test per Test Procedure 741.00 The test is progressing satisfactorily and 504 hr of Life Test have been completed The diodes were subjected to nine different electrical/thermal screening stresses All groups of a given diode type are now being subjected to identical life test condi tions. The resulting data will allow establishment of relationships between the response of each group to the initial stress and the subsequent life test behavior. Comparisons of parameter stability and reliability during life test will be made between groups. A final report will be issued during the second quarter of FY 19

Subtask 7 - Accelerated Life Test Program for NPN Planar Transistors (FY 1966 Funding)

During the negotiation phase of the procurement of the test contract, Purch Order K-382143 for $4,990 was issued for investigating several alternative meth of measuring thermal impedance. The work on the thermal impedance investigat was completed during February 1966, and the final report was received by JPL o March 3, 1966. Contract 950541 for the test program was issued February 23, 1 for $55,819.00. Based on the results of the preliminary study and additional inv gation at JPL, the test program was placed on Stop Work on April 8, 1966 for th purpose of determining changes in scope and allowing contract modifications. Fr the preliminary study, it was concluded the most difficult measurement method f thermal impedance was the most accurate. Since the value of this test program i largely dependent on precise knowledge of the applied stress, it was necessary to the more time-consuming method. The test program contract allowed the use of time-consuming methods and the intent of the preliminary program was to demon strate the required accuracy by several methods. It is estimated that work will resume on this contract in August 1966.

ubtask 8 - Review of Models and Methods of Accelerated Testing (FY 1967 Funding)

The objective of this subtask is to determine which of the existing mathematical nodels of accelerated life testing, and which test methods, are most worthy of addi-ional investigation. This will be accomplished by a careful review of the available iterature and by discussion with workers in this field. The various models and nethods will be compared for similarities and differences. Assumptions required in ach model will be delineated, and pertinent comments will be made regarding the hysical realizability of these assumptions. Recommendations will be made regard-ng modifications which would be most likely to increase the applicability of the nodels.

A Statement of Work and a Procurement Requisition for this effort have been rwarded to the JPL Procurement Division. It is expected that a RFQ will be issued ring the first quarter of FY 1967.

UBLICATIONS DURING FY 1966

ontractor Reports, Interim and Final

Hamman, Donald J., Tenth Quarterly Report, Battelle Memorial Institute, July 15, 1965, JPL Contract 950458.

Hamman, Donald J., Eleventh Quarterly Report, Battelle Memorial Institute, October 15, 1965, JPL Contract 950458.

Hamman, Donald J., Twelfth Quarterly Report, Battelle Memorial Institute, January 13, 1966, JPL Contract 950458.

Hamman, Donald J., Thirteenth Quarterly Report, Battelle Memorial Institute, April 15, 1966, JPL Contract 950458.

Abe, S. W., Final Report on Capacitor Screening Evaluation Test Program, Preston Scientific, Inc., November 17, 1965, JPL Contract 950864.

Interim Report on Diode Screening Evaluation Test Program, The Boeing Company, October 19, 1965, JPL Contract 950863.

Interim Report on Resistor Screening Evaluation Test Program, The Boeing Company, September 24, 1965, JPL Contract 950869.

Greer, Paul, and Davidson, Kenneth W., Final Report on Thermal Resistance Measurement Techniques Study Program, February 11, 1966, Motorola, Inc., Semiconductor Products Division, JPL P.O. K-382143.

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

ntractor Reports, Final

Hamman, Donald J., and Hanks, Carl, Final Report - Reliability of Electronic Components in a Nuclear Radiation Environment, Battelle Memorial Institute, July 1, 1966 (tentative), JPL Contract 950458.

FAILURE MECHANISMS
NASA Work Unit 186-70-01-07-55
JPL 384-00701-2-3540
L. W. Wright

OBJECTIVE

The objective of this work unit is to effect an improvement in the reliability of critical electronic parts by:

1. Determining the most likely causes of incipient microcracks in semiconductor devices, the relation of these cracks to long term reliability and methods by which these cracks can be detected and/or eliminated.

2. Establishing more positive techniques for the physical characterization of electronic parts.

ACTIVITIES DURING REPORT PERIOD

Subtask No. 1 - Parameter Distribution Study (FY 1965 Funding)

The data necessary for this study have been received. Part types from which the data were obtained include carbon film resistors, ceramic capacitors and tantalum capacitors. The total cost for data on 4000 parts of each type was $3,002.00. Computer programs necessary for study of the data are being prepared and a report on the results of the study is expected to be issued during the second quarter of FY 1967.

Subtask No. 2 - X-Radiation Effects Test (FY 1965 Funding)

Contract 951369 for $37,900.00 is now progressing satisfactorily and the test samples have accumulated approximately 150 hr of life test. Some difficulties were experienced with measurements at the onset of the program wherein approximately 0 devices were damaged. The tester programming was modified to prevent a recurrence of this type problem. As a result of this problem, the program was delayed by several months because of replacement parts procurement delays. The program is expected to be completed by June 1967.

Subtask No. 3 - Study of Semiconductor Microcracks (FY 1966 Funding)

Effort has been expended toward the investigation of two techniques related to detection of microcracks as well as other surface and subsurface semiconductor defects. The primary activities have been the following:

1. A Statement of Work has been prepared for a study employing the scanning electron microscope to locate semiconductor device defects. The intent of this study is to investigate methods which could possibly allow use of the scanning electron microscope as an in-line inspection tool for semiconductor defects prior to final package seal. Any defect which affects the electric field intensity

within the device is potentially detectable. Such defects could be either at the surface or within the bulk of the device. The Statement of Work has been forwarded to the JPL Procurement Divisio and it is expected that RFP's will be issued during the first quarte of FY 1967.

2. A purchase order has been issued for a sample quantity of a thermotropic material to determine its applicability to the locatio of hot spots across the surface of a semiconductor die. The mate rial is expected to be delivered in August 1966 and laboratory investigations will begin shortly thereafter.

Subtask No. 4 - Part Physical Characterization Studies (FY 1966 Funding)

The original intent of this subtask was to investigate several analytical techniques applicable in the physical characterization of electronic parts. Due to manpower limitations, however, effort has been restricted primarily to investigation of methods for the analysis of gas ambients within sealed electronic parts. In this regard, a RFP for a time and materials contract is currently out for bid and it is expected that the contract will be issued in August 1966. Two separate statements o work were prepared, one for gas analysis by mass spectroscopy and the other for ga analysis by gas chromatography. Depending on the outcome of the bidding, one or two contracts will be written. The mass spectroscopy method will be used for the general gas analysis problem and the gas chromatography method will be used specifically for detection of water vapor.

Subtask No. 5 - Failure Analysis of Electronic Parts

Due to manpower limitations, this effort was not initiated during FY 1966. A Statement of Work defining the effort was approximately 60% completed. This effor will be initiated during FY 1967 if funding is made available.

Subtask No. 6 - Design, Materials and Process Identification of Electronic Parts

The objectives in performing investigations to identify the design, materials and processes in electronic parts are the following:

1. To provide information which will allow a better understanding o part behavior.

2. To provide basic information which will allow intelligent apprais of new designs or process changes.

3. To provide detailed information about part construction and pote tial failure mechanisms prior to performing failure analysis.

4. To provide sufficient information to allow valid accelerated test and failure mode studies.

This program has been broadly outlined and the Statement of Work for a phase I effort has been prepared. A two-phase effort is planned where the phase I effort will be performed by three contractors who will study and carefully define th program. In phase II one of the three contractors will be named to carry out the

rogram. It is expected that the phase I contracts will be issued in October 1966. he program as outlined requires photomicrographs, diagramatic sketches and rocess procedures.

The Statement of Work and Procurement Requisition are currently in the roject Office awaiting disposition.

UBLICATIONS DURING FY 1966

None.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

SPACECRAFT TESTING EQUIPMENT AND TECHNIQUES (186-71)

ADVANCED SOLAR SIMULATION DEVELOPMENT

NASA Work Unit 186-71-01-01-55

JPL 384-10101-2-3750

R. E. Bartera

BJECTIVE

The long-range objective of this unit is to improve solar simulation apabilities in anticipation of flight project requirements by the development of new ystems and more efficient components.

)-FT SPACE SIMULATOR

The solar simulation system previously developed under this work unit and ow installed in JPL's 10-ft Space Simulator has been significantly modified to meet sting requirements of the Mariner Venus '67 project. Assistance was given in the esign of the new optical elements. The current solar system performance is listed Table 1.

Table 1. Solar simulation system performance

Beam size	6-ft hexagon
Intensity	300 w/ft^2
Field angle (apparent Sun diameter)	5° (±2-1/2°)
Uniformity	±5% (no steep local gradients)
Spectrum (approx. xenon)	
<4250A	10% (as measured)
4250 to 7500 A	39% (with spectrophotometer)
>7500A	51%

-FT SPACE SIMULATOR

Assistance continued to be given on a consultation basis to the design team sponsible for designing and fabricating the 15-ft solar system for the 25-ft space nulator modification now in progress.

The nickel coating development contract has gone quite well and the final step, ting the 23-ft-diameter mirror,will take place shortly. All necessary special ipment has been fabricated and is at the optical house awaiting final preparation of mirror. This coating is scheduled for mid-August 1966.

H-POWER ARC LAMPS

We have tested several more 20-kw arc lamps with moderate success. It ears that the manufacturer can produce such lamps with an average life of 200 hr;

this is half the life we consider necessary. The limiting factor on lifetime is anode erosion and degradation which is a function of anode temperature. We have designed an anode which will fit the 20-kw lamp and which incorporates a far superior water cooling configuration. Manufacturing procedures have been developed and the first anodes are now being fabricated. They will be shipped to the lamp manufacturer, installed in a standard 20-kw lamp and returned to JPL for evaluation. Meanwhile, we continue to test and evaluate lamps with anode configurations deemed better than those of previous lamps.

VARIARC

The design of this versatile laboratory arc lamp of 2-1/2 yr ago has been thoroughly reviewed and updated to include knowledge gained in the interval. A fabrication order was placed and we expect delivery during July 1966. We will use the VARIARC to obtain quantitative information on the effects of such parameters as electric and magnetic fields, pressure, electrode temperature and electron temperature on arc brightness.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. Youngberg, C., "Optical Fabrication of 116-in. Diameter Spherical Metal Mirror," SPS No. 37-34, p. 116, August 1965.

2. Youngberg, C., "Advanced Solar Simulator Development," SPS No. 37-37, p. 107, February 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

ADVANCED STUDIES (684)

PLANETARY AND INTERPLANETARY (684-30)
ADVANCED PLANETARY PROBE STUDY

NASA Work Unit 684-30-01-10-55
JPL 388-30150-2-3550
James Long

BJECTIVE

The long-range objective of the Advanced Planetary Mission is to increase the ate of knowledge of the outer planets (Jupiter and beyond). The basic purpose of e Study is to provide NASA and JPL Management with the necessary information to fine the magnitude of the Project.

In order to determine the effectiveness of the possible mechanization options meeting the primary objectives, this Study addresses itself to five specific jectives.

1. To evaluate and establish the magnitude of mission development and the technology required for "first step" flyby missions of the outer planets, with Jupiter flyby being taken as the focus mission.

2. To evaluate and mechanize, to the maximum extent possible, the Science objectives, "Jupiter Advanced Planetary Probe Science Objectives and Typical Experiments."

3. To develop and evaluate, in depth, several system mechanizations representative of various approaches, and interpretations of a minimum mission. Considerations will be given to "growth" from the sense of additional experimental sophistication and adaptability to planetary targets other than Jupiter.

4. To summarize tradeoffs of the several mechanizations and recommend, if possible, the system approach most compatible with the overall study objectives.

5. To identify major advanced developmental tasks required to realize mission feasibility.

SION MECHANIZATION EVALUATION AND CONCLUSIONS

This report summarizes the major constraints affecting the mechanization of proposed mission, and assesses the capabilities and requirements of the five eloped specific system mechanizations. The particular system mechanization that ears to be most consistent with this study and the mission objectives is recomded for further consideration.

IMARY OF MISSION AND MECHANIZATION REQUIREMENTS

Based on the analyses of environmental constraints, trajectories, scientific ctives, and spacecraft mechanization requirements, a number of conclusions and iirements can be stated relating to feasibility of mission and requirements of nology for a Jupiter flyby mission. The basic parameters affecting the

conclusions and recommendations are based on the power system, attitude control, and time-of-flight considerations.

Primary Power Source

A 200-w output primary power source would be required for a Jupiter flyby. This conclusion is valid for four of the five mechanizations developed although the mechanizations have varying degrees of complexity and capability. As an example the spin-stabilized mechanization, which requires a minimum of on-board controls and functions and has a minimum capability of performing omnidirectional science instrumentation, has the same power requirements as the medium data rate syster with body-fixed antenna. This has increased the telemetry capability of 8-1/3 bits sec and could mechanize direct science measurements of Jupiter during encounter The primary factors accounting for the required power level are the following:

1. For four of the five mechanizations developed, the communicat requirements resulted in a 20-w (output) transmitter. This, in turn, resulted in approximately 100 w of input power for the tel communication subsystem.

2. A 60% efficient power management system was assumed for re lated power requirements.

3. The power source was sized to allow for 20% degradation durin the mission. This sizing would accommodate thermoelectric e ment "shorting" or "opens" to achieve the desired confidence i mission success.

4. For the fifth mechanization, because of the system dependence antenna pointing, the power requirements would be reduced to 160 w (output), including 20% margin for degradation.

Radioisotope Thermoelectric Generator (RTG) Power Supply

The RTG is an obvious choice for primary power source. This conclusion based on the assumptions of full-time spacecraft operation and the 200-w output requirement. Because of the greatly decreased solar intensity, solar panels wou be large (approximately 700 sq ft), and would weigh approximately 320 lb. In add tion, thermal control requirements, power conditioning, power system integratio and expansion of the mission capability are more feasible for RTG power system than for large solar arrays. Although cost and technology comparisons were not investigated in depth, it would appear that both the large, light-weight solar arra and RTG's suitable for mission requirements represent a new development in technology.

RTG--Science Instrumentation Compatibility is a Major Design Consideration for Minimum Missions

Analyses and estimates of the sensitivity of scientific instruments measu low-energy fields, to the radiation "background" provided by relatively "clean" RTG's, indicate that a combination of shielding and separation distance would be required for compatibility. Analysis indicates that neither shielding or separati distance, exclusively, is a practical solution. The requirement for a separation

tance between radiation science and the RTGs exerts a profound affect on system nfigurations, especially for spin-stabilized concepts.

In view of the scientific importance of measuring the trapped radiation which y exist at Jupiter, and the fact that this measurement can be mechanized without ferential orientation of the instruments, it is extremely undesirable to compro- se the effectiveness of the instruments by a "take-it-or-leave-it" acceptance of the cecraft environment.

ect of Environmental Constraints

Design of the spacecraft for the Jupiter mission is significantly affected, far as weight and component selection considerations, by the environmental uirements. Because of the anticipated "debris" concentrations in the asteroid , protective bumper shields will be required for vulnerable areas. To minimize amounts of shielding, the electronic equipment, propellant tankage, and gas tank- should be centralized to the greatest extent possible. In addition, component ction and circuit design must emphasize "hardening" to the radiation levels anti- ted in the immediate vicinity of Jupiter.

st" Trajectory Advantages

The relatively "fast" trajectory (arriving at Opposition in approximately 500 20 days flight time) offers many spacecraft mechanization and operational advan- s. Depending upon which design constraints are emphasized during mission ition (e.g., launch weight, communication geometry), trajectory designs are mum energy transfers with relatively long flight time, or short flight time to imize the probability of success. For Jupiter missions, flight time is very sen- e to relatively small changes in injection energy (C_3).

The 500 to 520-day trajectory arriving at Opposition was selected as a base- design for the mission study. Injection energy requirements for a 20-day launch ow range from 103 to 110 km^2/sec^2 as compared to a minimum energy of n^2/sec^2 (one-day window) for a 900-day mission. It is recommended that a y of trajectories arriving at Opposition (500- to 520-day trajectories) be empha- l for mission consideration and launch vehicle developments. The following rs contributed to this recommendation.

1. The minimum "practical" flight time of this family of trajectories enhances reliability, minimizes operational support requirements and costs, and permits development of follow-on missions to incorporate information learned from precursor missions.

2. Because encounter occurs at Opposition (Sun, Earth, and Jupiter are in line), the communication geometry is the most favorable.

3. Variation of closest approach to Jupiter without trajectory correc- tion is minimized.

4. Favorable encounter geometry permits body-fixed science (for observation of Jupiter), and has relatively short Earth and Sun occultation periods (approximately 1.2 hr).

System Weights

For three-axis spacecraft mechanizations, a system weight of 685 lb (includ 10% design margin) is required for the "minimum science mission." Based on the system weight estimates and the mechanizations associated with these weights, the technological requirements and development associated with a Jupiter flyby missio is similar to the Mariner IV Mission, plus additional effort associated with the RT design and "long-life" requirements.

SPACECRAFT CONCEPTS EVALUATION

A brief summary of the mission capability for each system concept is presented to provide context for the recommendation of the system concept most consistent with mission requirements.

Spin-Stabilized Spacecraft

This mechanization has the capability of performing scientific missions tha not require preferential orientation such as would be required for the observation Jupiter. The specific trajectory correction mechanization considered (along the S line), does not appear attractive because of the weight penalties and operationa disadvantages involved. For absolute minimum missions, the requirement for trajectory correction should be eliminated. The variation in closest approach to planet would be plus or minus 8 planetary radii for the 500- to 520-day family of trajectories.

The major obstacle to the spin-stabilized concept it the requirement for compatibility between the RTG radiation and the low-energy particle-measuring science instruments. Because spin-stabilization concepts are configuration-sensitive, the need for separation distance between RTGs and science instrumentation resulted in the requirement for deployment of stabilization booms and weight achieve the necessary inertia relationships. This was reflected as a high system weight for very limited mission capabilities. The resulting large moment of ine about the spin axis resulted in the requirement for a "hot gas" precession system utilizing hydrazine as fuel. This system is generally considered somewhat more complex than the cold gas systems. From the system consideration, the only si ficant advantage is that a battery (as a secondary power source) would not be req mainly because of the absence of gyros.

Further spin-stabilized system disadvantages are the extremely limited c bility, with no significant "growth" capability for expanded scientific missions at Jupiter, and the awkward mechanization required to obtain telemetry. Because lack of a roll position reference, and therefore a need for a roll symmetric ante pattern, the telemetry subsystem would be a 1 bit/sec MFSK mechanization that would require a separate mode for spacecraft tracking. Although such a system feasible, it is not as satisfactory or straightforward as the PSK/PM telemetry system.

In summary, the spin-stabilized spacecraft does not seem to be an attrac mechanization if the radiation measuring science instruments require significan separation distances of approximately 15 ft from the RTGs. If further investiga and analysis indicate that large separation distances are not required, then the

pin-stabilized concept could be re-examined for applicability for "minimum" science nissions.

:oll Rate Limited - Low-Data-Rate System

This mechanization was developed for a direct comparison of an "active" attiide control system to a spin-stabilized system with similar capability. Due to the bsence of a roll position reference, this system had similar disadvantages related the telecommunications subsystem and the trajectory correction subsystem. ecause of the active attitude control system, the system was not seriously affected configuration constraints. The system weight for this mechanization is exactly e same as for the spin-stabilized system although the distribution of the weight is mpletely different. Primarily because of the awkward telecommunication subsysm mechanization, this system would not appear feasible for further considerations.

oll Position Reference - Low-Data-Rate System

This system mechanization was developed as a minimum three-axis system th the same roll symmetric antenna system as for the spin-stabilized concept and roll rate limited spacecraft. The principal reason for the third axis reference s to accomplish efficient trajectory correction. At one point in the study, developent of this mechanization appeared desirable because it was not evident that a emetry system using two-day doppler could be mechanized for a body-fixed antenna stem. This mechanization therefore would fill the "void" between the spinbilized system (and the roll rate limited system) and a three-axis system with a erable antenna. With the development of the system using the fan beam antenna obtain the desired telemetry performance) the roll position reference system ng the low data rate system (1 bit/sec MFSK) does not appear to be an attractive chanization.

dium Data Rate System - Body-Fixed Antenna

This system mechanization is a three-axis system that uses the roll position erence (Canopus) to perform arbitrary direction trajectory correction, and to proe a PSK-PM telemetry system that permits 8-1/3 bits/sec telemetry and concurt spacecraft tracking by two-way doppler. This mechanization is the most sistent with the requirements for minimum control functions and complexity, yet sesses reasonable data gathering and transmission capability (including encounter ence capability). If the minimum science mission permitted the resulting informa degradation, the spacecraft system could be further simplified by the elimination he trajectory correction requirement. This simplification would not only elimin the propulsion subsystem, but would significantly simplify the attitude control and &S subsystems. The variation in closest approach for the 500- to 520-day trajecies would be plus or minus 8 Jupiter radii.

dium Data Rate System - Steerable Antenna

This mechanization was developed to trade off possible simplification of the er supply requirements versus an increase in spacecraft control complexity uired to point the antenna to Earth. Although the problems associated with point the large antenna do not appear insurmountable, special consideration must be en to the thermal effects, i.e., the launch environment and increased solar prese torques due to the presence of the larger antenna (80-in.-diameter circular

paraboloid). The resulting decreased power requirements (180-w system output) do not appear to simplify the requirements significantly. In addition, the reduced transmitter power would present coverage problems early in the mission before the directional antenna could be utilized (a one-degree-of-freedom pointing system was investigated). The most reasonable solution to this early coverage problem (prior to 200 days after launch) would be a two-degree-of-freedom articulation system.

The most likely application for the "steerable" antenna system would be for expanded missions to other planets (or out-of-the-ecliptic mission) where the capabilities of the body-fixed antenna mechanizations are not adequate.

Figure 1 shows a possible configuration for a median data system using a body-fixed antenna.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

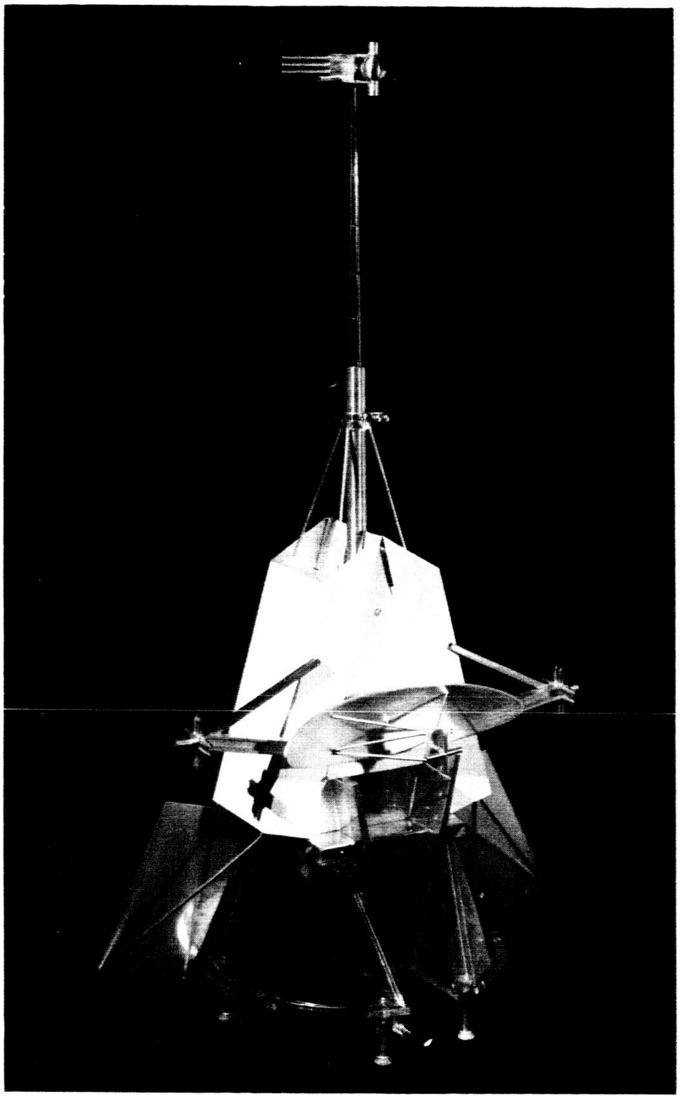


Fig. 1. Possible configuration for a median data system using a body-fixed antenna

ADVANCED PLANETARY PROBE MISSION STUDY

NASA Work Unit 684-30-08-01-55
JPL 388-30192-2920
K. H. Fishback

BJECTIVE

The objectives of this study program are to conduct a conceptual design and asibility study to develop first-generation spacecraft concepts adaptable for long-nge, long-duration planetary missions in the region extending from Mars to creasing greater distances from the Sun. The study shall include the conceptual sign of spacecraft systems to accomplish basic flyby missions of the planets piter, Saturn, and Pluto. In addition, the study will examine the growth potential the basis concepts through the use of modular design concepts to perform orbiter d planetary capsule entry missions. In accordance with these mission objectives study is expected (1) to establish the requirements of the mission in terms of ssion objectives and capability and resources required for mission accomplish-nt and (2) to evolve appropriate spacecraft system conceptual designs.

CHNICAL APPROACH

The mission study includes the selection of mission and scientific objectives, ich vary in complexity to provide sufficient flexibility for future project experi-nt selection. A scientific payload complement will be selected relative to each netary mission, and spacecraft conceptual design from the following broad science ectives of the study:

1. Measurement of the spatial distribution of interplanetary particles and fields.

2. Measurement of the salient features of planetary atmospheres with particular emphasis upon remote measurements from a flyby spacecraft.

3. Observations of the planets, i.e., visual, infrared, etc.

Science payloads will be configured by the study contractor on the basis of broad objectives relative to each spacecraft conceptual design capability and be concurred on by JPL in the initial phase of study.

Spacecraft conceptual and mission designs will be established in view of these ectives by: (1) establishing the functional requirements associated with each ective, (2) forecasting the applicable state of the art, (3) synthesizing system cept, and (4) reviewing these system concepts in terms of appropriate spacecraft tems.

GRESS

On December 29, 1965, a contract was awarded Thompson-Ramo-Woolridge ems to perform the study. During this report period the study was initiated by eduling a study planning meeting which was delayed as the result of TRW's desire hange the study leader and other key personnel. The planning meeting was held

on January 25, 1966, at which time TRW presented a matrix of missions as a function of launch vehicle capability. JPL held some reservation with this approa and scheduled subsequent meetings to clarify the interpretation of the scope of eff implied by the contract statement of work.

On March 15, 1966, a mid-term report was submitted to JPL by the contractor. After a review of the contents of this report it was determined to be insu ficient for a technical review and that additional work should be done prior to an oral review of technical progress. The oral review was given on April 21, 1966. The results of the review by the JPL Advanced Technical Studies group was that t generalized treatment of the mission requirements and spacecraft conceptual desi being presented had insufficient substantiating data for their validation. As a res of the review of the technical progress by JPL technical personnel, a meeting was held with TRW to brief them on known deficiencies in the study and to attempt to fi means to rectify this condition. After this meeting the contractor submitted a stu plan in the form of a final report outline. The plan submitted by the contractor w cover all the elements of the statement of work in sufficient depth for missions of current interest.

The planned approach calls for an in-depth study of a spin-stabilized, eart oriented spacecraft design concept, which uses a large body-fixed parabolic anten dish for communications and radioisotope thermoelectric generators for power. Other effort in the study will primarily be devoted to variations of the following nature: (1) design comparison with a 3-axis stabilized concept of the same scienc payload magnitude, (2) science payload, (3) multiple target capability, (4) orbiter entry configurations. In order for TRW to satisfactorily complete this effort, the have requested a four week extension in the schedule of performance at no additio cost to the contract.

During the mid-term oral presentation, Table 1 was presented which illus trates the configurations and missions being examined. Table 2 illustrates the comparable science payloads for these configurations. Figure 1 shows relations between launch vehicle capability, spacecraft weight and mission transit time up which the configurations were based.

Specific design problems which are identified relative to a spin stabilized spacecraft concept for a planetary mission that were insufficiently covered to as mission feasibility are:

1. Planetary science capability, particularly with respect to poi requirements.

2. Ability to perform trajectory corrections and the error analy

3. Open loop precessing maneuver mechanization and mission implications.

4. RF tracking of the Earth relative to acquisition and reacquisi

5. Large aperture antenna interface implications with attitude control.

LAN OF ACTIVITIES THROUGH NEXT REPORT PERIOD

A schedule extension of 4 wk is to be initiated by JPL to permit receipt of lequate study results under the contract. Such an extension will extend the final te for the study to August 11, 1966. During the remaining time JPL will monitor e contract to assure the most meaningful results from the study. A final report ll be submitted by the contractor, followed by an oral review of the study results. L will evaluate the study and prepare a technical critique of its results following mpletion of the contract.

JBLICATIONS DURING FY 1966

ntractor Reports, Interim and Final

Advanced Planetary Probe Study, Midterm Technical Progress Report, Thompson-Ramo-Woolridge Systems, 15 March 1966.

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

Table 1. Configurations and missions

Configuration Class	Spacecraft Propulsion[a]	Estimated Weight, lb	Mission: Launch Vehicle	Mission: C_3, km^2/sec^2	Mission: Planet	Mission: Transit Time, Years	Configuration No.
50-lb science payload (Spin stabilized, 10-ft shroud)	M		A/C/HEKS	~115	Jupiter Flyby	1.4	
					Jupiter Swingby to Saturn	3.2	
	M + OI	~1200	TIIIC/C	~95	Jupiter Orbiter	1.8	1A
	M + SI	547	A/C/TE364	93	Jupiter Flyby	1.9	
			TIIIC/C/TE364	175	Any flyby		1
100-lb science payload (Spin or 3-Axis stabilized, 10-ft shroud)	M	~850	A/C/HEKS	~97	Jupiter Flyby	1.7	2A
			TIIIC/C	~103	Jupiter Flyby	1.6	
	M + OI		TIIIC/C	~87	Jupiter Orbiter (marginal)		
	M + SI	915	TIIIC/C/TE364	145	Any flyby		2
	M + SI + OI	~2200	TIIIC/C/TE364	92	Jupiter Orbiter	1.9	
250-lb science payload (3-Axis stabilized, 20-ft shroud)	M	~1900	SIB/C/HEKS	~154	Any flyby		
			SV	~170	Any flyby		
	M + OI	3421	SIB/C/HEKS	112	Jupiter Orbiter	>1.4	
			SV	159	Orbiter[b]		3

[a] M = Midcourse, OI = Orbit Insertion, SI = Solid Injection. (TE364 used in launch injection sequence.)

[b] To permit orbital capture, additional weight would be devoted to orbit insertion propellant. This would also reduce injection C_3.

	50 lb	100 lb	200-250 lb
Interplanetary	Galactic cosmic ray Solar cosmic ray Solar plasma	Magnetometer Galactic cosmic ray Solar cosmic ray Solar plasma	Magnetometer Galactic cosmic ray Solar cosmic ray Solar plasma
	Magnetometer Micrometeoroid Radio occultation	Micrometeoroid Radio occultation	Micrometeoroid Radio occultation
Planetary	Television Trapped radiation Infrared radiometer	Television Trapped radiation Microwave radiometer Magnetometer Low-energy proton monitor Solar visual occultation Auroral detector	Television Trapped radiation Microwave radiometer Magnetometer Low-energy proton monitor Solar visual occultation Topside sounder Infrared radiometer Visual spectrometer VLF
	55 lb 27 w	108 lb 37 w	218 lb 56 w

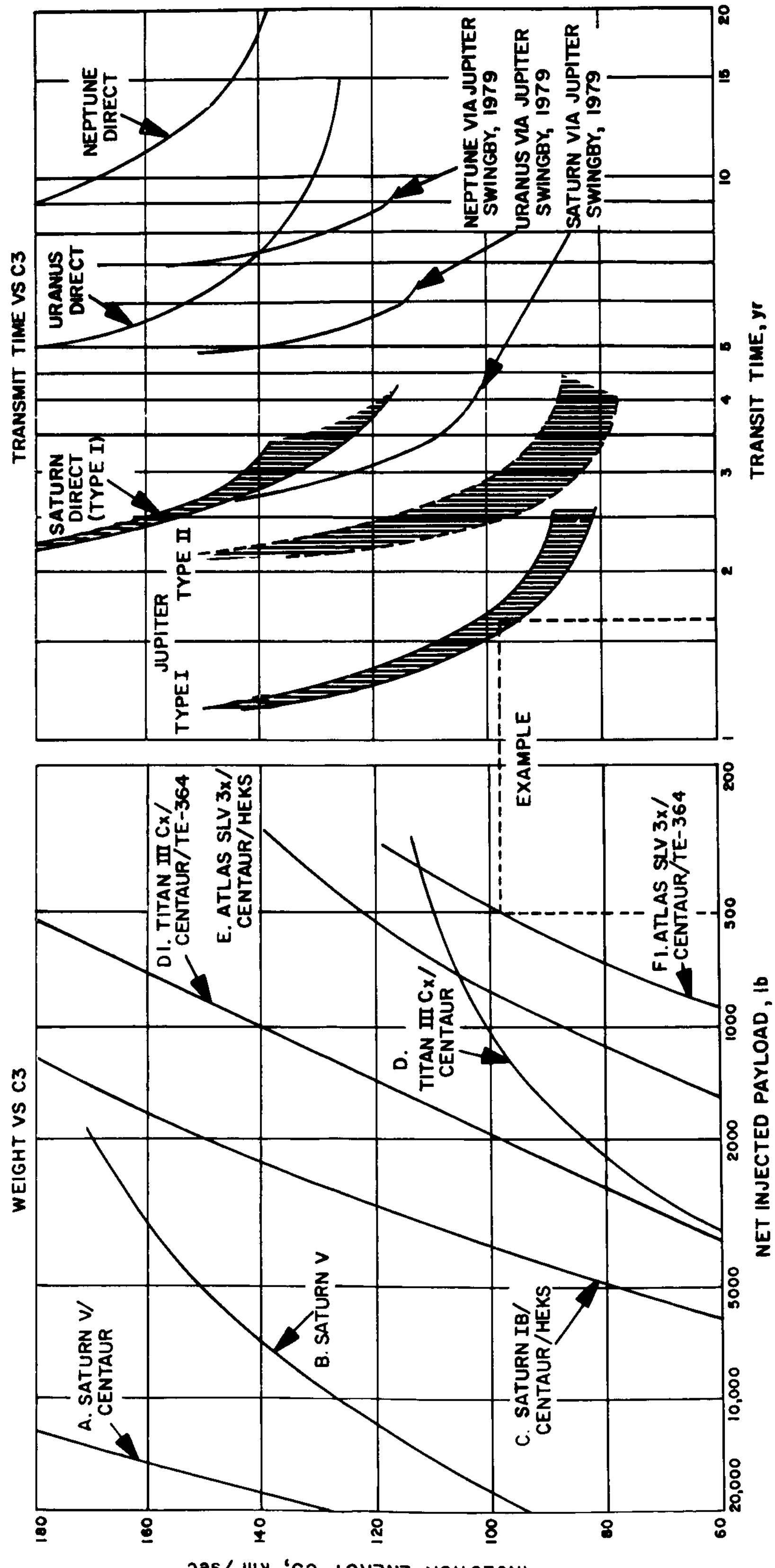


Fig. 1. Launch vehicles, spacecraft weight, and transit time

JUPITER FLYBY MISSION STUDY

NASA Work Unit 684-30-09-01-55
JPL 388-90101-2-2920
K. H. Fishback

OBJECTIVE

The objective of this study is the examination of spacecraft system design oncepts for first generation flyby missions of the planet Jupiter in the time period 973-1980. The study is expected (1) to establish the requirements for missions in erms of mission objectives, and the capabilities and resources required for mission ccomplishment, and (2) to generate appropriate spacecraft system conceptual esigns.

ECHNICAL APPROACH

In order that these objectives be carried out, the study will establish scientific ıyloads commensurate with the conceptual designs and in consonance with the follow-g broad science objectives of the study:

1. Interplanetary and planetary measurements of the spatial distribution of particles and fields. Measurements shall include but not necessarily be limited to:

   a. Magnetic fields.

   b. Solar plasma.

   c. Dust and micrometeorites.

   d. Ionized radiation.

   The trapped radiation belts of Jupiter are considered a special case of particle measurements and shall be presented relative to the design complexity required for their measurement.

2. Measurements of the planetary atmosphere of Jupiter which shall include, but not necessarily be limited to:

   a. Composition.

   b. Temperature.

3. Measurements of the physical properties of Jupiter which shall include, but not necessarily be limited to:

   a. Observation of the cloud cover and possibly gross features of the Jovian terrain.

The contractor and JPL will concur upon the science complement of each con-tual design in the early phase of the study.

The alternate means of accomplishing the set of mission objectives will be studied by: (1) establishing the functional requirements associated with these objectives, (2) forecasting the applicable state of the art, (3) synthesizing system concep and (4) reviewing these system concepts in terms of appropriate current spacecraft system design.

PROGRESS

On November 17, 1965, a contract was awarded to General Dynamic's Fort Worth Division for the performance of the study. A mid-term study report was sub mitted on February 17, 1966 followed by an oral presentation at JPL. During this time a technical review of progress to that point was made which resulted in discussions with the contractor relative to direction for the latter half of the study. A fin report was submitted to JPL on May 17, 1966, which was subsequently followed by an oral presentation at JPL.

The study was divided into three major areas of technical effort which were ascertained by JPL during the first week of study to satisfy the intent of the study objectives. These were: (1) mission planning, (2) spacecraft system design and analysis, and (3) spacecraft concept evaluation.

Mission Planning

The mission planning task was devoted to the science subsystem definition to describe the possible science requirements of the mission, and mission analysis t determine the mission performance requirements. The science subsystem definit explored all probable science experiments that would be of interest within the broa objectives established by JPL. Five scientific payload packages ranging in weight and order of spacecraft design complexity between 13 and 203 pounds were develop Tables 1 thru 4 illustrate the scientific payloads considered. The instrument and spacecraft design requirements were established for subsequent system conceptua designs studies. The mission analysis was directed at defining the mission requi ments and determining the mission performance possible in the 1973-1980 time periods with the launch vehicles specified for the study. Typical of the results pr duced by this task are mission planning charts (Fig. 1) for each launch opportunit 1973-1980. More detail data was provided for purposes of system design and illu trating possible mission variations including encounter geometry, variation in mi sion performance, launch vehicle, launch opportunity, launch period, etc.

Spacecraft System Design and Analysis

Consistent with the study objectives the contractor synthesized four spacec concepts which exemplify the spacecraft design requirements and complexity requ to perform a range of scientific missions. The concepts developed were based up a minimum degree of complexity to perform particle and fields experimentation i interplanetary space out to Jupiter distance, in the near field of Jupiter and its trapped radiation belts. Intermediate and full science missions were developed which would be capable of particle and fields, planetary atmospheric and planet oriented experimentation.

Table 5 summarizes the characteristics of the four spacecraft concepts developed by this study.

A major design problem considered in the study was the form of spacecraft stabilization which would satisfy the mission requirements and design criteria for a range of spacecraft concepts which vary in mission capability and design complexity. This is illustrated by Fig. 2 and 3 which provided the rationale for the design approaches used.

Other design problems addressed by the study which were considered new or unique to a Jupiter mission were:

1. Radiation Protection Study Approach and Conclusions

- Define various radiation environments

  Galactic cosmic

  Solar

  Earth-trapped

  Jupiter-trapped

  RTG emissions

- Evaluate equipment operating principles, materials, and parts

  Consider worst potential problem areas for each environment

- Galactic cosmic and Earth-trapped-no problems

- Solar radiation - thermal control coatings

- Jupiter-trapped-semiconductors, optical glass and materials, Sun sensors, star tracker

- RTG - semiconductors, radiation detection instruments, safety

- Jupiter-trapped radiation is primary problem

  Shielding not satisfactory because of the high energy of the radiation.

  Judicious selection of radiation resistant equipment recommended.

  Scintillation and Cerenkov radiation might well be above star irradiance levels.

- RTG radiation can be accommodated without penalty to the Spacecraft design.

  Integrated neutron flux over 600-day period is less than semiconductor threshold established in short term tests.

  RTG neutron and gamma flux at detectors not expected to b above cosmic radiation.

- No unusual procedural requirements are necessary for radiatic safety considerations during prelaunch.

2. Effects on Radiation Detection Instruments

- Expected RTG neutron flux -2 x 10^3 n/cm^3-sec (1 m, no shielding).

- Expected RTG gamma flux - 11 mr/hr (1 m, no shielding).

- Lower limit of expected cosmic ray flux - 1 mr/hr in ionizati Chamber and 0.6 counts/sec in GM tube.

- 5-mev Neutron Flux required to produce 1 mr/hr in ionizatio chamber 1.97 n/cm^2-sec.

- Separation distance required for 1 mr/hr in the ionization cha ber from RTG gamma flux-3.25 m.

- In the GM tube, 1.45 x 10^{-6} count rate per unit flux is produc by 2 mev neutrons.

- Separation distance required for 0.6 counts/sec in the GM tub from RTG gamma flux-2.24 m.

3. Jupiter S-band Occultation Experiment

- Doppler rates at encounter require a DSIF receiver threshold sensitivity no less than -160 db.

- Performance margin of 10 db in the received signal is desira

- At 6 AU and without considering the attenuation and scatterin spacecraft required ERP = 75 db.

- A 50-w transmitter and 10-ft parabolic antenna (Concept D) produces an ERP = 82 db.

- Expected attenuation and scattering degradation of signal of 2 to 30 db.

- Conclusion - success of S-band occultation experiment with practical spacecraft designs is questionable.

4. Encounter Doppler Rate Considerations

- For a four Jupiter radii perijove, the doppler rate of the received signal approaches 30 cpsps.
- For DSIF receiver threshold of - 160 dbm, allowable doppler rate is 150 cpsps - but - for DSIF receiver threshold of - 170 dbm, allowable doppler rate is 4 cpsps.
- Low-data-rate telemetry (>4 bits/sec) requires - 170 dbm threshold.
- Therefore, the spin-stabilized spacecraft (Concept A) signal will be lost for approximately 13 hr of any pass within reasonable distance of Jupiter.

Other design problems addressed of a special nature may be found in the final udy report are:

1. General relativity experiment.
2. Radioisotope thermoelectric generator design and integration.
3. Autonomous spacecraft control.
4. Data compression technique and analysis.
5. Long communications distances and delay times.

acecraft Concept Evaluation

This task was related to and produced results for mission performance, probaity of mission success, development requirements which resulted in PERT III e of scheduling and costing methodology by which mission cost estimating was formed relative to the spacecraft concepts and launch vehicles.

nned Future Activity

The final study report has been disseminated within JPL and is under evalua-. A report will be published in mid-July in the form of a study critique as a ult of the JPL evaluations.

BLICATIONS DURING FY 1966

tractor Reports, Interim and Final

A Study of Jupiter Flyby Missions, Mid-Term Technical Progress, General Dynamics Fort Worth Division, FZM-4572, February 17, 1966 (under JPL Contract No. 951285).

2. A Study of Jupiter Flyby Missions, Final Technical Report, General Dynamics Fort Worth Division, FZM-4625, May 17, 1966 (under JPL Contract No. 95128

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

Table 1. Scientific experiment packages
(Full scientific experiment package)

Instrument	Weight, lb	Power, w
Extended magnetometer	8.0	7.0
Energetic particle detector	2.5	0.4
Cosmic dust detector	2.5	0.2
Expanded photometer	6.0	5.0
TV camera (TV-II)	30.0	20.0
Plasma probe	7.0	2.5
Microwave radiometer	28.0	6.0
Infrared radiometer	5.0	3.0
Ion chamber	3.0	0.5
Infrared spectrometer	16.0	5.0
High-energy proton directional monitor	4.0	0.6
Cosmic ray spectrum analyzer	18.0	2.0
UV Visible spectrometer	20.0	10.0
Medium energy proton directional monitor	3.0	1.0
Bistatic radar	15.0	8.0
Radio noise detector	5.0	2.0
Null radio seeker	5.0	2.0
Radar altimeter	25.0	10.0
	203.0	85.2

Table 2. Intermediate scientific experiment package

Instrument	Weight, lb	Power, w
Part 1		
Extended magnetometer	8.0	7.0
Energetic particle detector	2.5	0.4
Cosmic dust detector	2.5	0.2
Expanded photometer	6.0	5.0
TV camera (TV-I)	15.0	10.0
Plasma probe	7.0	2.5
Microwave radiometer	28.0	6.0
Infrared radiometer	5.0	3.0
Ion chamber	3.0	0.5
	77.0	34.6
Part 2		
Extended magnetometer	8.0	7.0
Energetic particle detector	2.5	0.4
Cosmic dust detector	2.5	0.2
Expanded photometer	6.0	5.0
TV Camera (TV-I)	15.0	10.0
Plasma probe	7.0	2.5
Microwave radiometer	28.0	6.0
Infrared radiometer	5.0	3.0
Ion chamber	3.0	0.5
Infrared spectrometer	16.0	5.0
High energy proton directional monitor	4.0	0.6
Cosmic ray spectrum analyzer	18.0	2.0
	115.0	42.2

Table 3. Minimal scientific experiment package

Instrument	Weight, lb	Power, w
Extended magnetometer	8.0	7.0
Energetic particle detector	2.5	0.4
Cosmic dust detector	2.5	0.2
Visible photometer	2.0	1.5
TV camera (TV-I)	15.0	10.0
Plasma probe	7.0	2.5
	37.0	21.6

Table 4. Spin-stabilized spacecraft experiment package

Instrument	Weight, lb	Power, w
Extended magnetometer	8.0	7.0
Energetic particle detector	2.5	0.4
Cosmic dust detector	2.5	0.2
	13.0	7.6

Table 5. Variation in design of spacecraft developed

Characteristic	Concept A	Concept B	Concept C	Concept D
Injected weight, lb	531	717	1058	1581
Science subsystem support	20 lb, 10 w	40 lb, 25 w	115 lb, 45 w	200 lb, 85 w
Antenna	10/14 db, 6°/4° fixed	27 db steered 1 deg freedom	30 db steered 2 deg freedom	35 db
Transmitter power, w	25	25	35	50
Bit rate at 6 AU, bits/sec	1	17	33	133
Data storage capacity, bits	22×10^6	48×10^6	49×10^6	292×10^6
Data compression ratio	10 to 1	10 to 1	10 to 1	10 to 1
Sequence and control	Mariner IV design	Mariner IV design	Mariner IV design	On-board spacecraft Control and data management
Midcourse propulsion	60 m/sec	60 m/sec	90 m/sec	90 m/sec
Spacecraft stabilization	3 axis/spin	3 axis	3 axis	3 axis
Power required at end, w	195	240	360	480
Science scan platform	None	MA IV type	Jupiter tracking 2 deg freedom	Jupiter tracking 2 deg freedom
Mission success probability (Contractor estimated)	Nil	Nil	Nil	Nil
Program cost, 2 flights including launch vehicle and operation	$150,700,000	$178,640,000	$236,420,000	$288,100,000

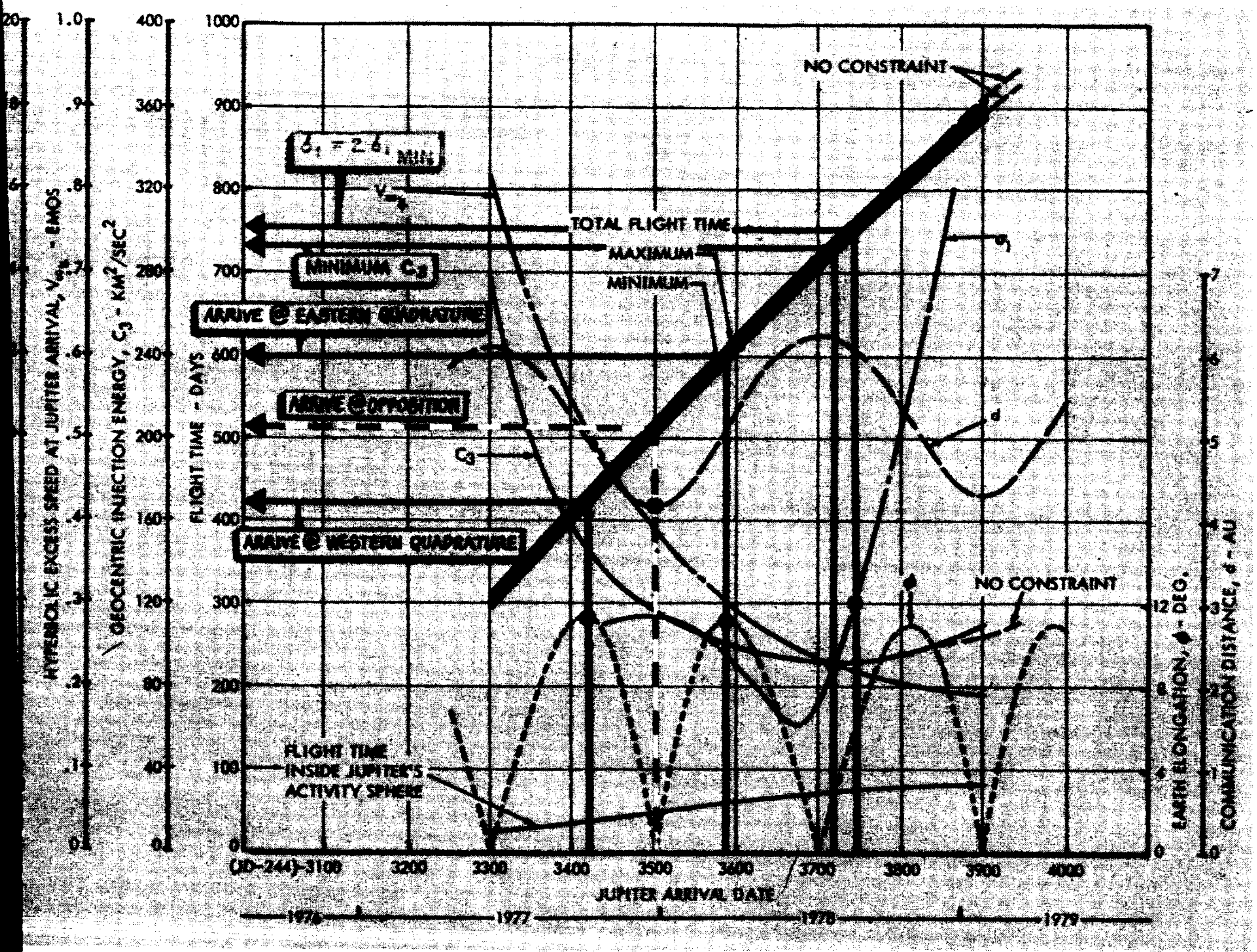


Fig. 1. Mission planning chart, 1976 launch

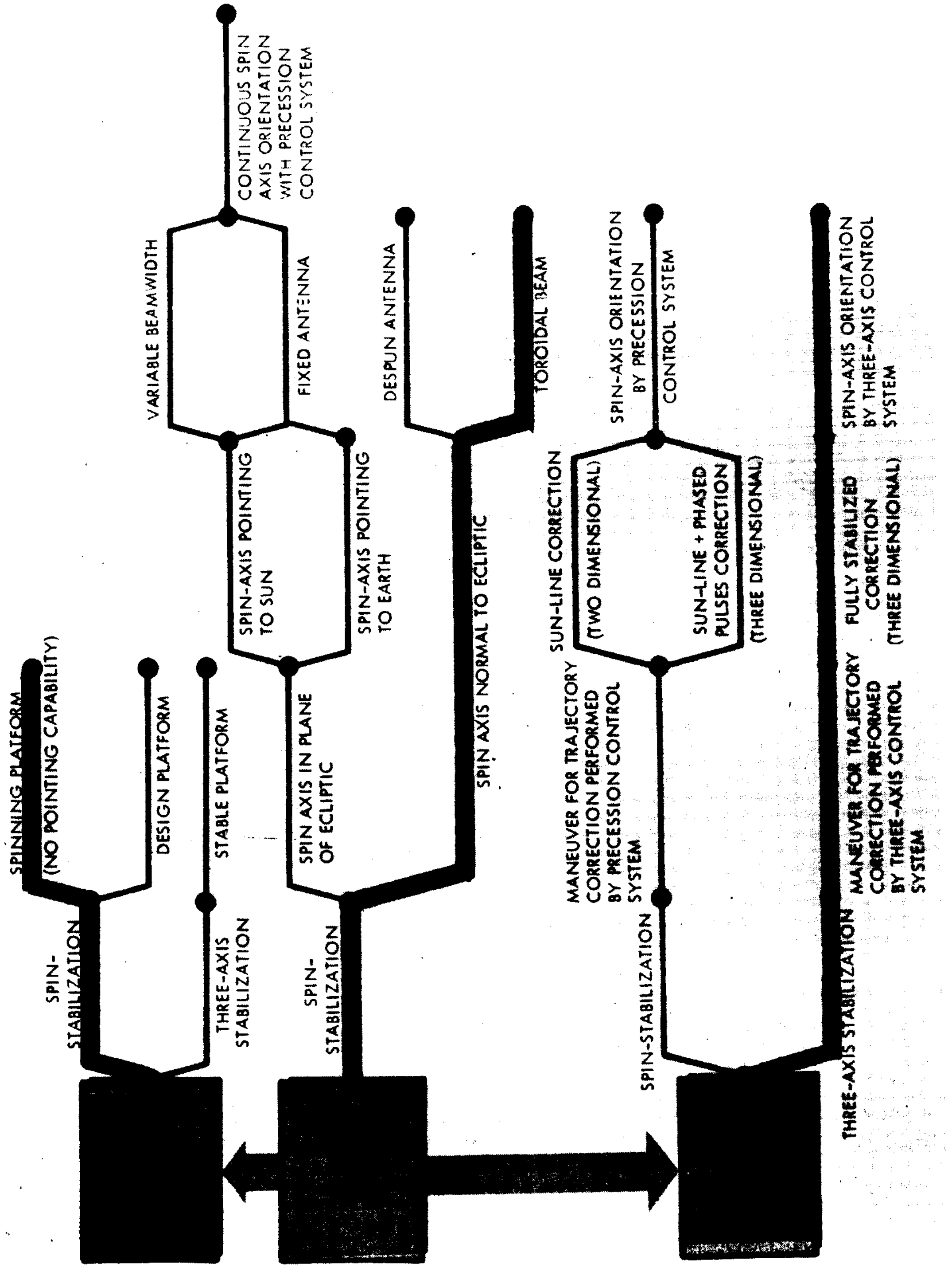


Fig. 2. Design alternatives for spin-stabilization

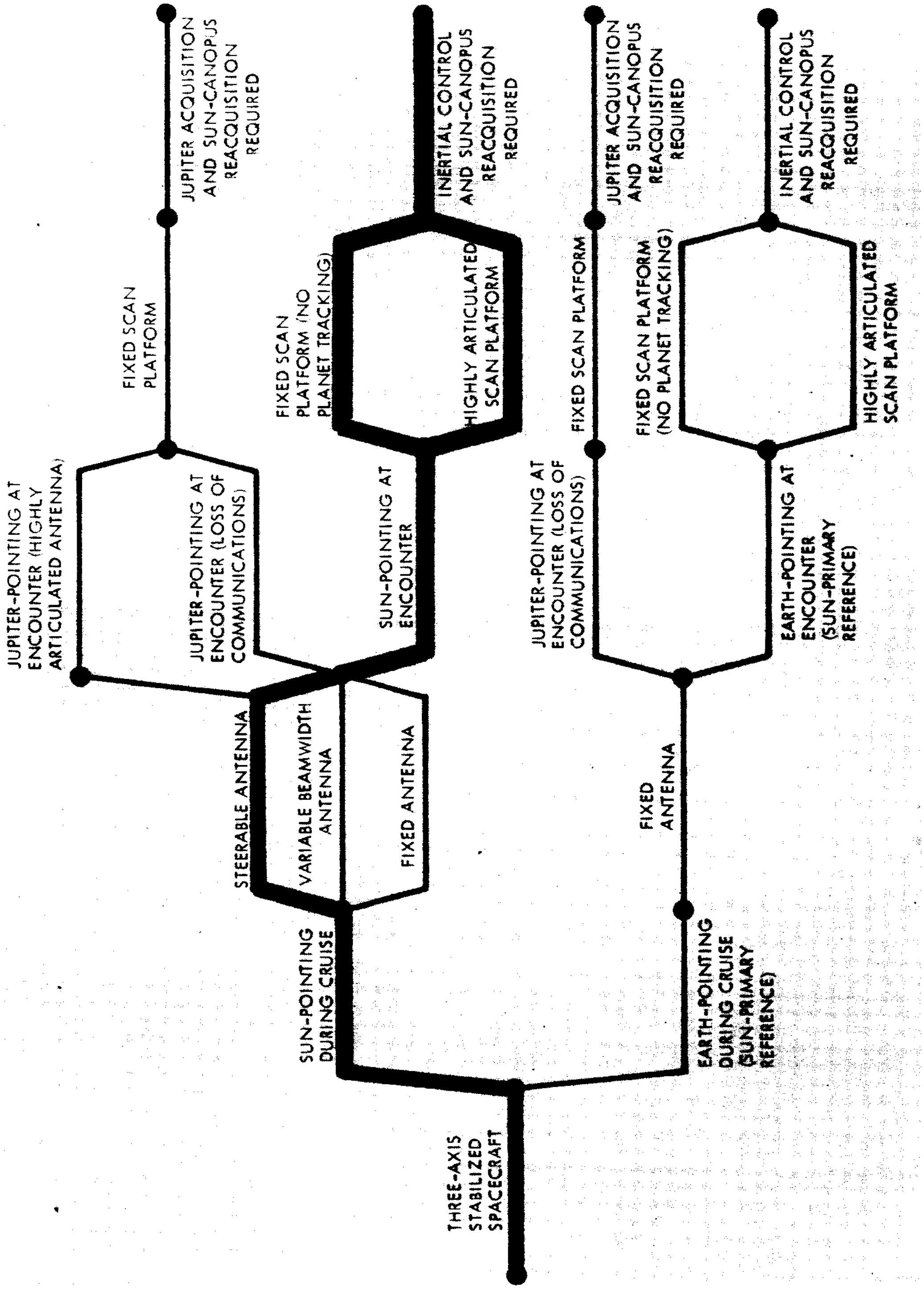


Fig. 3. Design alternatives for three-axis stabilization

Part B
Physics and Astronomy

PHYSICS AND ASTRONOMY (188)

MAGNETODYNAMICS IN SPACE (188-36)

MAGNETIC PHENOMENA

NASA Work Unit 188-36-01-01-55
JPL 385-60101-2-3280

E. J. Smith

BJECTIVE

The objective of this work unit is (1) to investigate naturally-occurring xtremely low frequency (3 to 30000 Hz) magnetic field variations generated within, r above, the ionosphere, to study their origin, modes of propagation, and associa- on with solar terrestrial phenomena; and (2) to utilize techniques for the detection nd analysis of signals observed at the Earth's surface which may be applicable to xperiments on satellites and space probes.

Simultaneous measurements are made above and below the ionosphere ilizing a satellite and a ground-based observatory. OGO-2 contains, and OGO's and F will contain, search coil magnetometer experiments measuring magnetic eld variations from 1 to 1000 Hz. JPL personnel are operating a remote field site ere naturally occurring magnetic (and electric) field variations are detected and corded on magnetic tape.

ROGRESS

The recording of observatory data has been automated through use of a ner-controller of special design. The timer-controller permits acquisition of ta at routine intervals (e.g., 5 min out of every hour) as well as at irregular ervals when OGO-2 is in the vicinity of the field site (±40° latitude of longitude). computer program has been written to determine the latter using OGO-2 trajectory rameters. A paper tape is then punched and used to control the on-site tape corder for several days at a time thereby eliminating the necessity to have the servatory continuously staffed by JPL personnel.

OGO-2 has continued to provide intermittent data since its launch in mid- tober 1965. Magnetic tapes containing data transmitted by the OGO-2 Special rpose telemetry have been obtained from the Stanford University Electronics search Laboratory, who operate their own tracking station, and from GSFC. In te of a relatively high level of spacecraft-generated interference in the frequency ge being studied, several distinct species of signals have been identified in the O-2 data, in particular whistlers and hiss. A preliminary investigation of signals n simultaneously at the ground has not yet yielded any positive results.

Analysis of routinely acquired surface data has continued with emphasis on diurnal variation in signal level, the observation of Earth-Ionosphere resonances l a search for signals having a distinctive frequency-time behavior. Regarding latter, a gliding tone at frequencies between 30 and 100 Hz has been observed on nerous occasions and is now being investigated in detail.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

ADVANCED MAGNETOMETER

NASA Work Unit 188-36-01-03-55
JPL 385-60401-2-3230
D. D. Norris

)BJECTIVE

The objective of this work unit is (1) to complete development of a second eneration low-field vector helium magnetometer of inherent reliability and to extend ıe development of the second generation system to provide high incremental resolu- ion with wide dynamic range, and (2) to perform operational evaluations over tem- erature ranges compatible with lunar, cis-lunar, planetary and interplanetary ıissions.

ROGRESS

Prior to selection of the ALSEP payload, exploratory work was done to com- ıre the fluxgate magnetometer with the helium magnetometer for lunar surface pplication. A temperature test was conducted to measure fluxgate stability between 150 and +150°C in apparatus depicted in Fig. 1. The test results indicated in gamma drift in the fluxgate over this temperature range, which represents an pper bound because of thermally induced changes in the magnetic shield. With this ıcouraging result, further work was done on fluxgate circuitry in an attempt to iminate known sources of electronic offset. Some of the positive results of this fort are reported in JPL SPS 37-36, Vol. IV.

After ALSEP payload selection, comparative work on low-field fluxgates helium magnetometer was dropped; but the circuitry developed to study this oblem was adapted to an earth-field measuring device and was delivered to . W. S. MacDonald for attitude information use on the spark chamber balloon periment. Photos of this device are shown in Fig. 2 and 3. The sensor used was Mariner R prototype sensor.

Work has continued on the non-magnetic thermal vacuum facility. All pro- rements are complete, and the magnetic shields have been delivered to JPL. nctional testing of the rotatable hot/cold gas transfer mechanism has been per- med. The only remaining work to be done is to modify the Group 3231 thermal cuum chamber to allow alignment of the rotating mechanism with the magnetic ields. The completion of this task is being performed under the Mariner Venus project as this facility will be used to requalify and calibrate the flight magne- ıeters for that program. A schematic of the thermal apparatus is shown in Fig. 4.

The second generation helium magnetometer electronics breadboard was mpleted and checked out and incorporates the changes in sweep vector amplitude l frequency discussed in prior reports. Recent developments in analog integrated cuits made it feasible to change this system. With no change in basic system sign, the breadboard was redesigned using integrated circuits and again checked satisfactorily. The present breadboard uses 129 components, which is a reduc- n of over 700 parts compared to the Mariner C instrument. The instrument ver consumption is now less than four watts, as opposed to seven watts for the riner C magnetometer.

The effort on helium lamp and cell reliability has been terminated without entirely satisfactory results in finding a screening technique. The most significant finding in recent work has been the serious effect of impurities on lamp performance, and it is now felt that production control can be maintained through the use of present knowledge, although a quantitative technique of measuring lamp and cell pressure should be developed for future programs.

Figure 5, the helium magnetometer sensor evolution, shows what can be done with present knowledge. Our present effort on sensors is directed toward the Mariner Venus '67 task, so no actual fabrication work is being performed on the second generation sensor.

No further work will be performed under this task; but the knowledge gained in low-field magnetometry has provided valuable data, which is presently being used on Mariner Venus '67, and has improved our capability for future work on magnetometers.

PUBLICATIONS DURING FY 1966

1. Bunn, J.S., "Phase Stable Frequency Doubler," JPL SPS No. 37-36, Vol. IV, pp. 204-207, October 1, 1965 to November 30, 1965.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

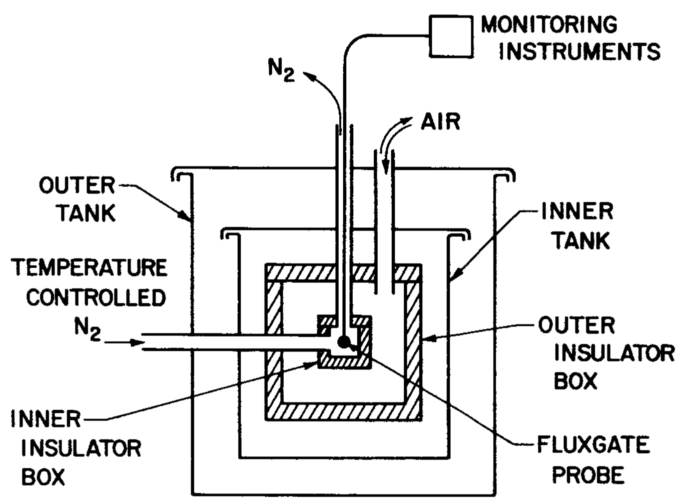


Fig. 1. Advanced magnetometer fluxgate temperature drift test configuration

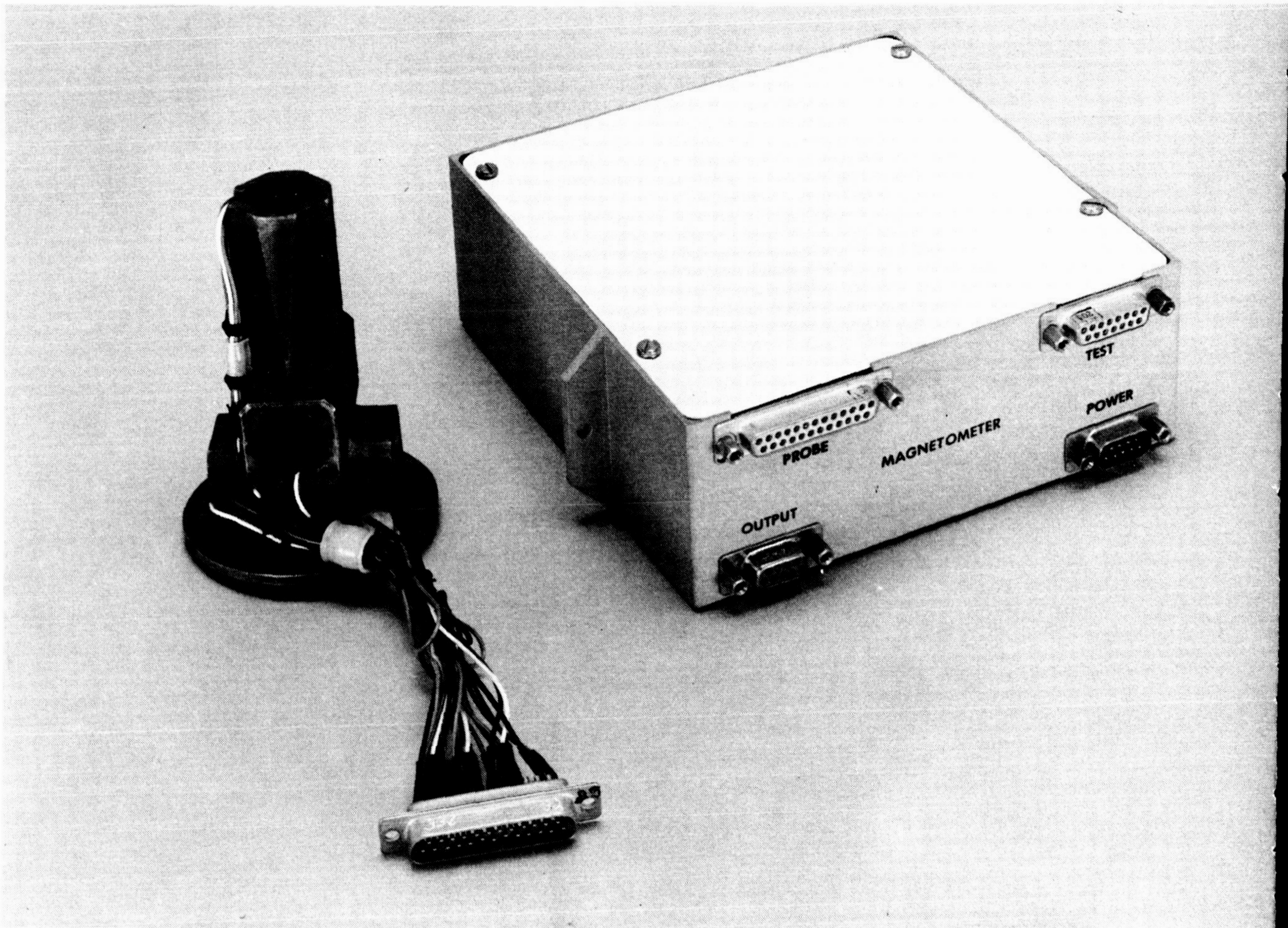


Fig. 2. Advanced magnetometer balloon attitude fluxgate (front)

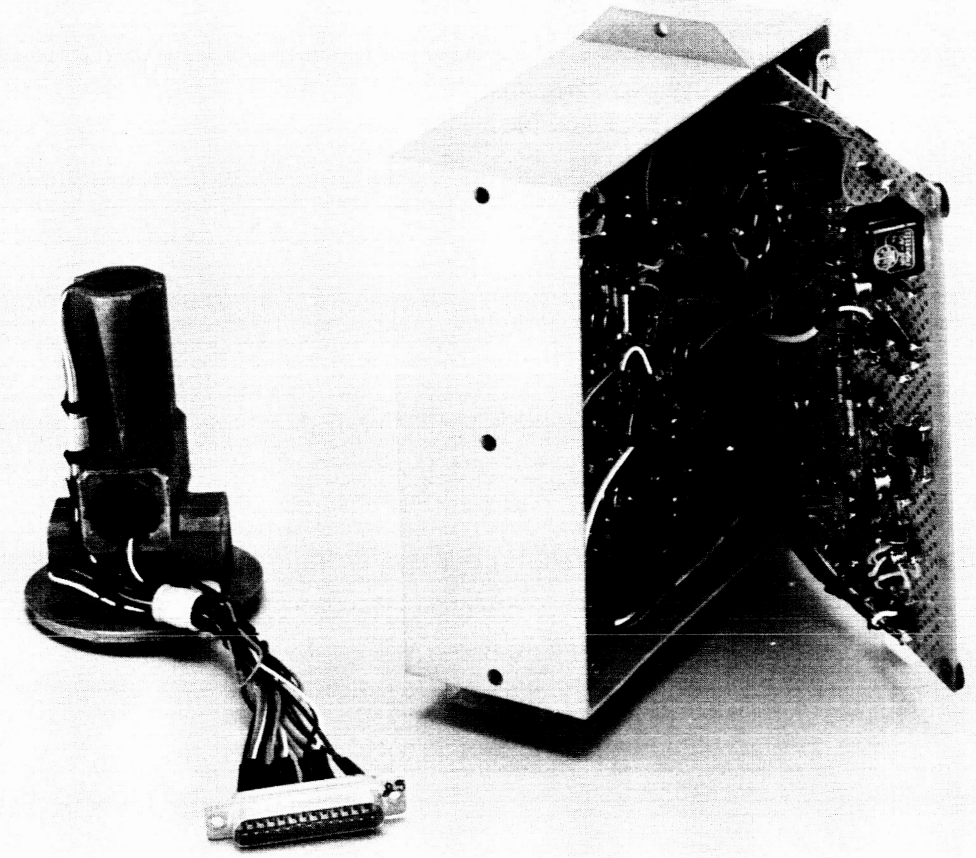


Fig. 3. Advanced magnetometer balloon attitude fluxgate (bottom)

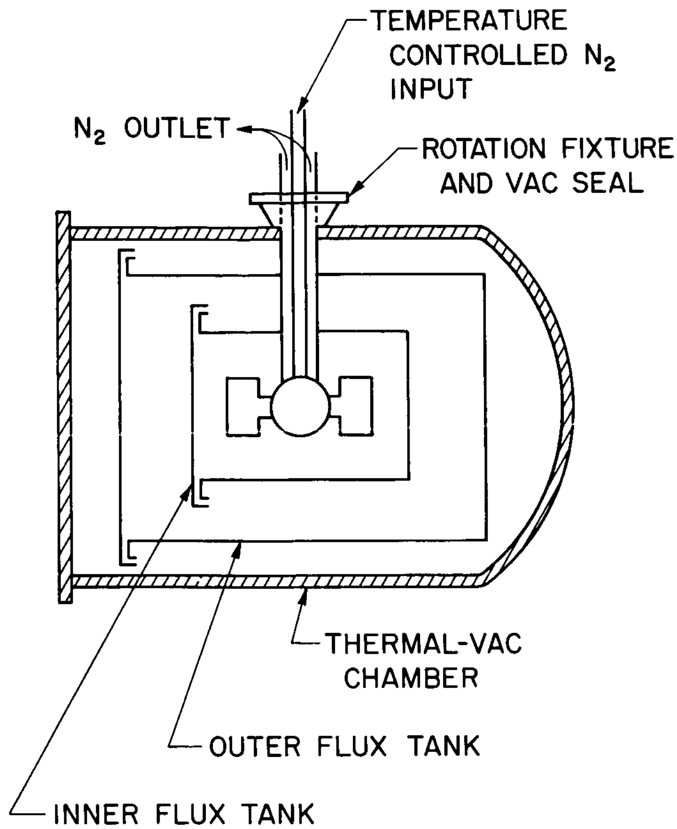


Fig. 4. Advanced magnetometer environmental offset test configuration

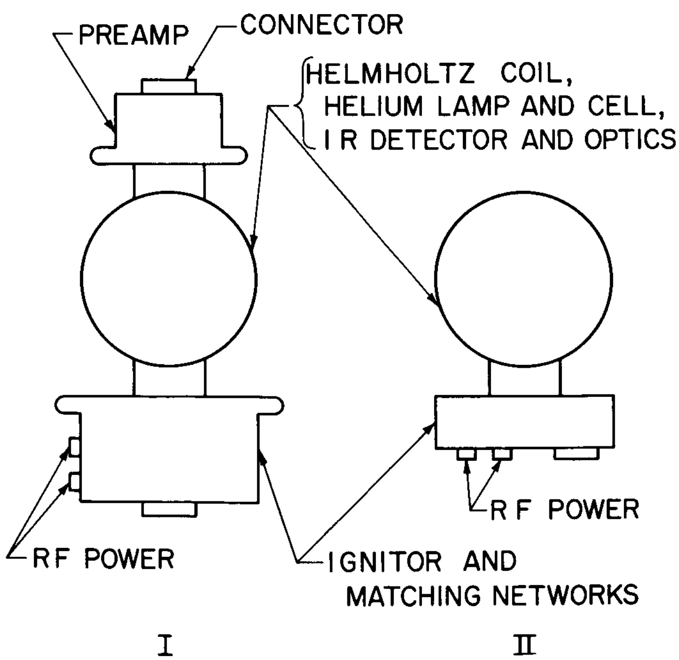


Fig. 5. Advanced magnetometer helium magnetometer sensor evolutions

ENERGETIC PARTICLES (188-46)

RADIATION EXPERIMENTS

NASA Work Unit 188-46-01-01-55
JPL 385-60301-2-3280

W. S. McDonald

BJECTIVES

The objective of this work unit is to develop new experimental concepts and chniques for the study of high-energy radiation, both planetary and interplanetary. rrent interest centers around a spark chamber designed for the study of energetic otons, alpha particles, and neutrons associated with galactic cosmic rays and lar-flare radiation phenomena.

The primary objective of the spark chamber program for FY 1966 was to epare for two balloon experiments using progressive developmental models of the ark chamber system. The first of these balloon flights (a low magnetic latitude ght) was scheduled to be made from Palestine, Texas during the spring of 1966. e second (a high magnetic latitude flight) is to take place from Fort Churchill, nada during late July and early August 1966. These chambers were designed to asure the energy spectrum and angular distribution of protons above 50 Mev and ha particles above 200 Mev.

OGRESS

Since the last report, fabrication of the Palestine flight system has been comted. Key components of this system are shown in the photographs in Fig. 1, 2 3. The spark chamber system gondola is shown in Fig. 1. It is 80 in. long and in. in diameter. During flight this gondola is contained in an air tight cylindrical minum housing with walls 32 mils thick. This in turn is surrounded by a crash sing of lightweight tubular aluminum construction wrapped with styra-foam crash s. The gondola is suspended from the balloon in such a way that the cylindrical s is horizontal. As shown in Fig. 1, the gondola is divided into four compartnts. The right-hand compartment contains the chamber and its high-voltage sor plus the chamber sensing and reading circuitry. The next compartment cons the analog and pulse height analyzer circuitry associated with the scintillators, ddition to the digital data processing system. The next two compartments con-, respectively, the tape recorder system and the battery plus the power supply.

The spark chamber gaps are shown in Fig. 2. Each of the four gaps consists wo plates with 5 mil wires strung 16 to the inch on an insulating frame, so that t of the area of the plate is open. Each wire passes through a magnetic core. n a charged particle passing through the chamber triggers the high voltage and ws a spark, the core associated with the particular wire that carries the spark rent is flipped, and that wire can be identified by examining, electronically, the e of the core system associated with a given plate. Adjacent plates have their es strung in mutually orthogonal directions. Therefore, identification of the rent-carrying wires on the plates is equivalent to identification of the position in chamber at which the spark occurred. Such information in the four gaps allows direction of the particle to be inferred.

On each outside face of the spark gaps are two planar plastic scintillators, optically isolated from each other. The housing for the spark gaps, scintillators a associated photomultiplier tubes is shown in Fig. 3. A charged particle passing through the two inner scintillators will trigger the spark chamber high voltage. Particle energy information is obtained by observing the number of scintillators penetrated and by performing a 256 channel pulse-height analysis in each scintillat

At the time of this report the spark chamber gondola was in the process of shipment to Palestine for a flight scheduled during the first week of July 1966. Th flight data is about 3 mo behind the schedule of the last report. The primary rea for the delay was a high-voltage breakdown problem encountered in the 1200 v dc supply voltage to the photomultipliers. In the original chamber design these high voltage lines were placed inside the spark chamber housing and were hence expose to the neon-helium gas inside the chamber. Breakdown of the 1200 v in this gas m ture persisted, even though all possible breakdown points appeared to be well insu lated. Attempts to remedy the problem by making minor changes failed to give a system of satisfactory reliability against breakdown. It was finally decided to tak the time to redesign and rebuild the system so that the high voltage dc was nowhe exposed to the chamber gas mixture. This solved the breakdown problem comple

Because of the delays in the Palestine flight and manpower limitations it w decided to fly a system at Churchill which made only minor modifications to the Palestine system. Instead of a new omnidirectional chamber originally planned Churchill, the Palestine chamber will be used and the omnidirectional coverage obtained by using a motor driven gear system to periodically rotate the look angle the chamber. Fabrication of the additional hardware required for the Churchill f is essentially complete.

On a second priority basis, a laboratory spark chamber has been fabricat to check the experimental feasibility of detecting the direction and energy of fast neutrons by filling the chamber with helium-3 and analyzing the recoil proton and triton in the reaction.

$$ {}_0n^1 + {}_3He^2 \rightarrow {}_1H^1 + {}_1H^3 + 0.764 \text{ Mev} $$

Results of this neutron experiment should be forthcoming in FY 1967.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

1. McDonald, W. S., and Lewyn, L. L., "The Spark Chamber Program," SPS 37-35, Vol. IV, September 1965.

2. Lockhart, R. F., "Low Noise Amplifier for Solid State Detectors," SPS 37-35, Vol. IV, September 1965.

3. Lewyn, L. L., "A Nanosecond Rectangular Wave High Voltage Modulator fo Spark Chamber," SPS 37-36, Vol. IV, November, 1965.

Lewyn, L. L. "Commutated Analog-to-Digital Converter," SPS 37-37, Vol. IV, January, 1966.

UBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

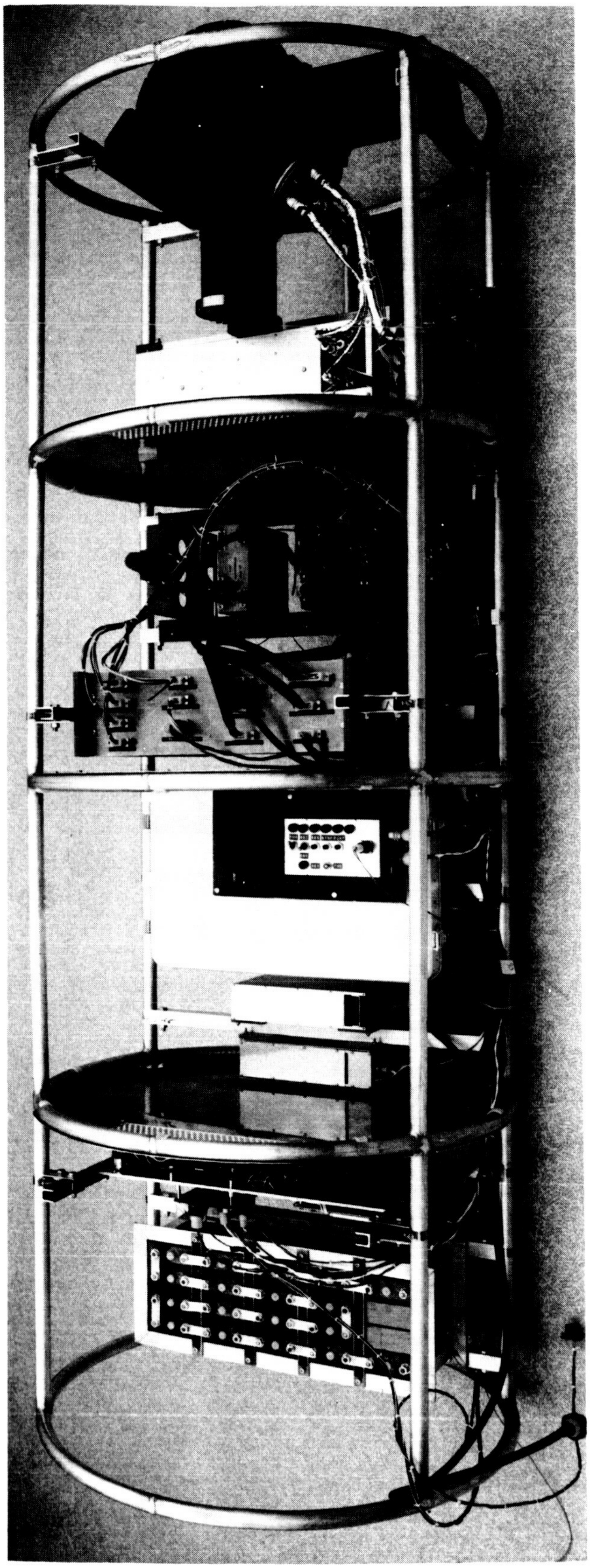


Fig. 1. Spark chamber system in flight gondola

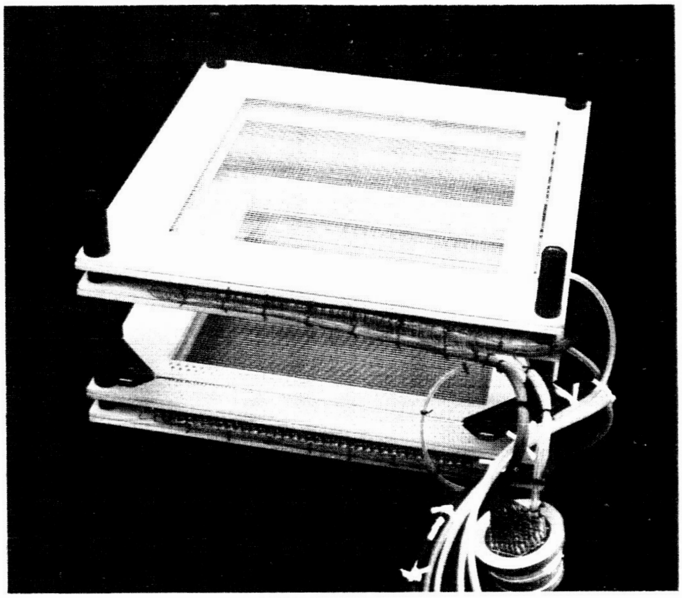


Fig. 2. Spark chamber gaps

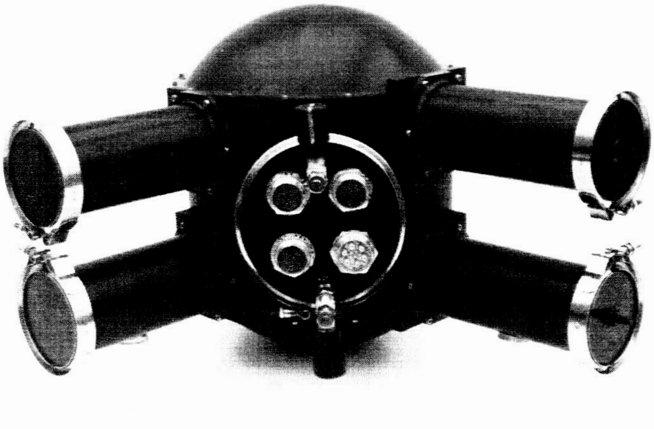


Fig. 3. Spark chamber housing

SOUNDING ROCKETS (879)

EXPERIMENTS (879-10)
AEROBEE ULTRAVIOLET DAYGLOW AND AURORA
NASA Work Unit 879-10-01-55
JPL 745-10101-0-3280
C.A. Barth

)BJECTIVE

The objective of this work unit is to conduct ultraviolet experiments from ockets in the Earth's upper atmosphere on the ultraviolet dayglow and aurora and the ltraviolet albedo of the Earth and Moon.

NSTRUMENTS

JPL participation in this task effectively terminated on December 31, 1965.

A filter photometer prepared under this task flew piggy-back on W.G. Fastie's ocket from Ft. Churchill in February 1966. Another payload, assembled and cali-ated, and then shipped to the University of Colorado, was flown by them in March.

JBLICATIONS DURING FY 1966

None.

JBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

DATA ANALYSIS (385)

FIELDS AND PARTICLES DATA (385-48)

ANALYSIS OF FIELDS AND PARTICLE DATA

NASA Work Unit 385-48-01-01-55
JPL 375-80101-2-3280
M. Neugebauer
C. W. Snyder

JECTIVE

The objective of this work unit is to conduct scientific analysis of fields and ticles data from Mariner-2 and OGO spacecraft.

RINER-2 OBSERVATIONS OF THE SOLAR WIND. AVERAGE PROPERTIES

A paper has been prepared summarizing the properties of the positive-ion nponent of the solar wind observed during the 4 mo of the Mariner-2 flight to and t Venus in 1962. The protons' average velocity and temperature were approxi- ely 500 km/sec and 1.7×10^5 °K, respectively. Several streams of hot, high- ocity plasma were observed to recur at 27-day intervals, with peak velocity and perature values of ~830 km/sec and 9×10^5 °K. One of these streams probably sted for at least 18 mo. Between streams, the velocity dropped to ~320 km/sec, le the temperature was $\sim 3 \times 10^4$ °K. Near 1 AU, the average density was approx- tely 5 protons/cm^3. The density was usually highest at the leading or western e of each stream, with a maximum value of ~80 protons/cm^3. Otherwise, the sity varied inversely with the plasma velocity. The ions' velocity, temperature, density were calculated from ~35,000 energy/charge spectra by fitting the data to ropic Maxwell-Boltzmann distributions in a reference frame moving away from Sun at the solar-wind velocity. A model in which the protons and alpha particles equal thermal velocities gives a better fit to the observed spectra than does an al-temperature model. The spectra usually had high-energy tails which became e pronounced at the higher plasma velocities. The velocity, temperature, and n-energy tail were not strongly dependent on distance from the Sun, whereas the sity varied approximately as the inverse square of this distance.

The paper will appear as a JPL Technical Report and, in abbreviated form, in Journal of Geophysical Research.

RK IN PROGRESS

Work is just starting on the combination of the Mariner-2 plasma and gnetic-field data:

1. Writing a computer program which will compare the direction and strength of the interplanetary magnetic field with the computed plasma properties. A magnetic tape containing the corrected magnetometer data has been supplied us by P. Coleman of UCLA.

2. Preparing a magnetic tape which will contain calculated plasma parameters appropriate for use in the interplanetary atlas being prepared by C. P. Sonett and D. Colburn of NASA-Ames.

3. Searching for indications of magnetohydrodynamic waves.

PUBLICATIONS DURING FY 66

Papers Presented at Meetings and Symposia

1. Neugebauer, M., and Snyder, C. W., "Mariner-2 Observations of the Solar Wind," European Study Group on Space and Laboratory Plasmas, Frascati, Ita[ly], May 9 - June 3, 1966.

Publications in the Open Literature

1. Mackin, R. J., Jr., and Neugebauer, M., editors, The Solar Wind, Pergamo[n] Press, 1966. Also co-author of two papers in this volume:

   a. Neugebauer, M., and Snyder, C. W., "Mariner-2 Measurements of the Solar Wind."

   b. Snyder, C. W., and Neugebauer, M., "The Relation of Mariner-2 Plasma Data to Solar Phenomena."

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

Publications in the Open Literature

1. Neugebauer, M., and Snyder, C. W., "Mariner-2 Observations of the Solar Wind I. Average Properties," Journal of Geophysical Research, October 1, 1966 (accepted for publication).

JPL Technical Reports

1. Neugebauer, M., and Snyder, C. W., Average Properties of the Solar Wind a[s] Determined by Mariner 2, JPL TR 32-991 (to be published). (This is a longer[,] more complete account of the material in the journal article listed above.)

Part C

Bioscience

BIOSCIENCE (189)

ENVIRONMENTAL BIOLOGY (189-54)
BIOSATELLITE FLUOROMETRY EXPERIMENT
NASA Work Unit 189-54-01-04-55*
JPL 386-40100-2-3200

H. O. Kruger

)BJECTIVE

The objective of this work unit is to study primate metabolic balance during rolonged weightlessness with Biosatellite D. The concentrations of calcium, reatine, and creatinine in the urine will be measured during flight. The work at PL is divided into developing assay methods, developing the technology for auto- ating these methods, and designing and fabricating the flight instrumentation.

ENERAL PROGRAM

In its final design the flight instrumentation consists of two analyzers, a mple acquisition and disposal system, sequencers and a data storage system -- all side a pressurized case. There is also the necessary ground equipment for simu- ing the spacecraft and for calibration of the instrument.

As a result of a preliminary test program, a major redesign was found neces- ry. Simulated tests of zero gravity conditions on solutions resulted in changes in xing. This necessitated considerable development in valves and modification of the quencers.

The original spacecraft urine transport system was to have delivered filtered ne to the JPL instrument. The spacecraft manufacturer found this to be impracti- , and the sample acquisition system went through several modifications in order to d an arrangement which would operate with raw urine.

As a result of these changes, the case would no longer accommodate the three lyzers originally proposed, and the urea analysis was eliminated.

The final engineering design could not be completed until the development k was successful. The design is now frozen, and almost all drawings are at the ricators.

During the next 6 mo, a qualification unit, three analyzers and three aero- ce ground equipment consoles will be completed.

MATE URINALYSIS (JPL 301-10102-2-3260; JPL 386-40102-2-3260)

A base line study of primate urinary Ca^{++}, urea, creatinine, and creatine was le using urine from three primates in the laboratory of Dr. Crockett at Harbor eral Hospital. Rate of urine excretion, pH of urine, the concentrations of ium, creatinine, creatine, and urea were measured on 6-hr pooled samples for lays. These primates were kept under conditions closely resembling actual flight

intly funded under NASA Work Unit 981-10-30-01-55 and 981-10-30-02-55.

conditions with respect to feeding, watering, and temperature environment. As a result of this base line study, Dr. N. Pace of University of California, Berkeley and Dr. J. Rho of JPL have proposed the following ranges for the JPL urine analyzer:

Calcium - 0.25 to 20 millimols/liter

Creatinine - 3 to 35 millimols/liter

Creatine - 3 to 25 millimols/liter

An analysis will be made on the excretion rates of calcium, creatine and creatinine of the primates at UCLA to obtain the normal distribution curve for these constituents. These data will provide a basis for the selection of the potential flight primates as well as the basis for the instrumental design goal.

Further base line studies will be made on the urinary Ca^{++}, creatine, and creatinine on flight simulated primates at UCLA system test.

FEASIBILITY STUDIES (JPL 301-10102-2-3260; JPL 386-40102-2-3260)

Urine Sampling Unit

A new design was developed for acquiring a urine sample during each delive by the spacecraft urine system. A 1-milliliter sample is removed from the main line during each 10-milliliter delivery. The sample is flitered through a coarse (300μ) mesh to remove large particles which might occlude small passages in the analyzer. The sample is removed by a piston assembly which stores the integrate 6-hr sample, and which also is used to drive the sample into the analyzers. The unidirectional flow of urine is accomplished by using check valves in series before and after the piston cylinder storage. Special check valves with soft seats were developed to accommodate the sludge in the urine sample.

Analyzers

Units were developed for each of the tests to be performed. Each unit is equipped with suitable test cell, reference cell, plunger drive, heater coil, therm couple control, rotary selector valves, lamps, optical filters, and detectors. Th volume of the test cell in which reactions and measurements are made is 0.080 m liter. This miniaturization permits a severe reduction in the fluids required for and rinse. The plunger piston is used with a suitable micrometer drive and a cou to enable quantitative addition of reagent and sample. This piston is also used to accomplish mixing, by driving the reactants back and forth across the entrance orifice into a chamber in one of the rotary valves. The test cell is wound at each with insulated resistance wire to allow for temperature control. The thermocont ler is mounted on the wall of the test cell, which is fabricated from pyrex. An optical path is produced across the test cell fitted at one side with a detector and the other with a miniaturized tungsten lamp. Appropriate filters are placed befo the lamp and detectors. The system is double beam, the sample lamp being used illuminate reference and test cell; however, the reference cell has its own detect which is in bridge circuit with the test cell detector.

The rotary selector valves have presented the most difficulty, and special aterials and design have been employed to insure proper operation and leak-free aintenance. Rotary valves are driven by a miniaturized motor and gear arrange-ent and are stopped by a small selector wafer switch for alignment of the fluid ssages.

In conjunction with the sampler and analyzer a flexible controller was fabri-ed. This permits either the automated or manual mode of operation and extensive nges in the program, e.g., increase in the number of mixing cycles, can be omplished by simple adjustment in a few minutes. The flexible controller is uable for development, systems tests, and failure analysis.

The disposal unit has a plunger drive, which rinses the analyzer and the fluid s into the downstream urine line, past a back pressure regulator, and into the uum waste tank of the spacecraft. The rinse pump and back pressure regulator e been incorporated in the same unit with the urine sampler for compact operation.

The following tests have been performed:

1. Extensive functional tests of all components and subsystems.

2. System test of integrated subunits.

3. Calibration tests using prepared solutions of known concentration. These were performed to develop calibration curves and to examine operational efficiency. These were particularly valuable to establish mixing of reactants as a function of changes in position, density, and geometry.

4. System test using collected primate urine of determined concentrations.

5. System test directly attached to primate (at UCLA) which had been surgically catheterized.

6. The following analyzer ranges were selected:

   Calcium - 2.0 to 20 millimols/liter

   Creatinine - 3 to 35 millimols/liter

   Creatinine plus creatine - 3 to 60 millimols/liter

The following work will be performed in collaboration with the Flight ument Program:

1. Calibration of flight units.

2. Support for test program of subsystem.

3. Support for operation during flight preparation.

FLIGHT INSTRUMENTATION (JPL 386-40101-2-3220; JPL 301-10101-2-3220; 301-90101-1-3220)

During the second half of FY 1966 the group has done the following:

1. Released the interface requirements for the electrical, mechan- ical, urine and gas pressurization systems, and the telemetry readout format.

2. Performed environmental and life testing on the test cell plunge assembly subsystem, valve drive subsystem, lamp driver and data preamplifier subsystem, and a simulated analyzer subsyst

3. Completed preparations for proof pressure test pressurization the experiment case.

4. Selected the vendor to fabricate the integrated circuit assembly portions of the experiment and completed 80% of the Qualificati Test Unit Data Handling System by the vendor.

5. Successfully integrated the following prototype electronics sub- systems: Calcium logic sequencer, creatine-creatinine logic sequencer, data handling system, experiment 26 v power con- verter and regulators, simulated spacecraft timing commands, and simulated data read-in levels. (These subsystems are now functioning as a single system.)

6. Completed over 1700-hr life test of the prototype data handling system without any component malfunction.

7. Completed all electronic drawings for vendor fabrication of int grated circuit and welded module assemblies.

8. Completed 80% of all mechanical drawings needed for fabricat of the various mechanical subsystems.

9. Completed fabrication, assembly, and preliminary testing on 10 subassemblies.

10. Completed procurement of all components needed for the asse of the Qualification Test Unit with the exception of several ite used in the Urine Sample Acquisition subassembly.

11. Completed fabrication of all components needed in the Aerosp Ground Equipment No. 1; (Target Assembly Completion Date AGE-1 is 6/25/66.)

12. Completed a preliminary design evaluation of all analog circu used in the experiment (data amplifiers, power supply regulat thermal controllers, and motor drive circuits).

13. Completed the subsystem test console and performed preliminary performance evaluation prior to using it for the evaluation and checkout acceptance tests of the vendor-fabricated integrated circuit and welded module subassemblies.

14. Completed the environmental tests on several subsystem assemblies with no component failures.

In addition to the completed items, a concentrated effort is being made to eeze the design in the two major problem areas. The development of a suitable equencing valve for the sequencing of fluids has been a much more difficult problem an originally anticipated. Valve designs are completed to a point where an acceptle component design exists. However, efforts are continuing in order to improve e operational and reliability characteristics of the sequence valves. The second ea is that of developing suitable check valves for the urine sample acquisition sysm. A design has finally been developed which appears capable of operating satisctorily in the presence of the "worst case" urine samples as delivered by several st subjects in earlier phases of the testing program.

There appear to be no other serious technical problems to be solved which uld prevent successful completion of this experiment's intended mission, as the erfaces are now defined.

BLICATIONS DURING FY 1966

blications in the Open Literature

Rho, J. H., and Behar, J., "Urinary Urea Procedure Modified for Automation," at American Chemical Society, 150th National Meeting, Sept. 12-17, 1965.

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

EXOBIOLOGY (189-55)

GROWTH AND PHOTOSYNTHESIS STUDIES

NASA Work Unit 189-55-02-01-55
JPL 386-51101-2-3260
G. L. Hobby

)BJECTIVE

The objective of this task is to develop a life detection experiment to test Iartian surface matter for the presence of light-dependent fixation of atmospheric ases, especially carbon dioxide.

TUDIES OF THE PHOTOSYNTHETIC ACTIVITY IN SMALL TERRESTRIAL SOIL AMPLES

Five desert soils were selected for study to determine what levels of photo- nthetic activity could be expected in sample sizes of the order of a few milligrams. ne selection was made based on the estimated algae concentration, the pH, the rticle-size distribution, and optical opacity.

All soils tested had been stored under air dry conditions for 2 to 3 yr before ey were used in these experiments. They were collected from widely different ographical regions. These were Mecca Hills, Thermal, California; Katmai National onument, Alaska; the Kau desert, Hawaii; and one sample was obtained at JPL. All mples were furnished by Dr. Roy Cameron of JPL.

Samples of these soils ranging from 50 to 400 mg were incubated in radioac- e carbon dioxide in the light, and in the dark, for time periods ranging from 3 to hr. These were accompanied by sterilized controls. Light intensities used were 0 and 900 ft-c, and the concentrations used in the incubation chambers were 076 to 0.38μC/Ml.

Two of these five soils took up significant amounts of radioactivity when incu- ed in $^{14}CO_2$ in the light compared with dark-incubated samples. One soil took up levels of radioactivity both in the light and in the dark, after 48 hr incubation, l two of the soils showed no activity for this time period. Estimates of the algae all soils were obtained by dilution tube counts. In one coil in which no CO_2 fixa- n was detected, no algae growth was obtained in the dilution tubes, while in the er soil algae grew at 10^{-3} dilution in 14 days. The algae counts for active soils re 10^4 and 10^5 per gram. The two photosynthetically active soils also exhibited nificant dark fixation of $^{14}CO_2$ over sterilized controls.

Estimates were obtained of the sensitivity of the technique as it is presently formed in the laboratory, relative to the photosynthetic activity of Chlorella. orella innoculae of 10^1 to 10^6 cells were incubated in $^{14}CO_2$ in the light for 5 hr. oculae estimated at 10^3 to 10^4 cells gave easily detectable C-14 uptake.

In order to estimate the amount of $^{14}CO_2$ taken up by chemical and adsorptive cesses in the soil under the conditions of these experiments, three soils of differ- particle-size distributions and pH were exposed to 0.38μC/ml of $^{14}CO_2$ for 15, 60, and 120 min in the dark. In all cases the CO_2 uptake was as high or ner than expected biological uptakes for these time periods. As expected the non- ogical uptake seems to be mainly a function of the pH of the soil. There was

little apparent effect of particle size distribution on the amount of $^{14}CO_2$ adsorbed. Desorption occurred slowly after the samples were removed from the $^{14}CO_2$ atmos phere. However, after treatment with concentrated HCl the $^{14}CO_2$ of all samples w reduced by factors of 10 to several hundred.

The results obtained so far indicate that:

1. Some desert algae can be reactivated very rapidly after they ha remained dormant for prolonged periods of time.

2. The present sensitivity levels of the techniques now used are su ficient for testing very small samples of some soils for photo- synthetic activity.

3. Treatment with concentrated HCl to remove adsorbed $^{14}CO_2$ pi to measuring biologically fixed C-14 is an adequate procedure.

4. The total radioactivity accumulated, which is sensitive to steri ization but not to treatment with strong acids, is caused by both dark as well as light-dependent carbon-14 fixation.

Since one soil which exhibited no CO_2 uptake in these tests did produce slo algae growth when added to culture medium in the dilution tubes, the reason for th lack of activity needs to be determined. These experiments will be repeated, add different kinds of culture media to the samples to test for possible nutritional defi ciency. Incubation times will be extended and $^{14}CO_2$ uptake compared with the tin interval at which growth begins to appear in dilution tubes. Other factors such as light intensity, temperature, the effect of anaerobic conditions and the use of muc larger samples sizes will be studied.

Further tests of soil samples to determine relative activities due to dark a light-dependent CO_2 fixation are necessary. Other areas to be studied are: (1) removal of adsorbed CO_2 without treatment with concentrated acids, (2) evalu- ation of techniques involving the combustion of the sample after incubation and me suring the accumulated radioactivity in terms of the $^{14}CO_2$ released, and (3) exte sion of the testing to a variety of other soil types.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

FLUOROMETRY
NASA Work Unit 189-55-02-02-55
JPL 386-50201-2-3260
J. Rho

JECTIVE

The long-range objective is to develop photometric techniques for the logical exploration of Mars. These will include fluorescence and spectrophoto-tric analyses for the detection of life and its organic products or precursors. The rent objectives are to develop fluorometric procedures for detecting the presence amount of organic matter in soil samples, and to obtain general information ut its nature, to develop photometric assays for specific biochemical components oil, and to develop photometric methods for the detection and growth of micro-anisms in soil samples.

ANIC ANALYSIS

To understand the chemical mechanisms of the formation of fluorescent vatives of pyrolysis in sealed tubes, an attempt was made to characterize the lucts by means of their absorption spectra, fluorescence properties, and other ical and chemical characteristics. The 300°C pyrolysis products from L-leucine other amino acids were separated by thin-layer and gas chromatography. By use traviolet and infrared spectrophotometry, fluorometry, and mass spectroscopy most highly fluorescent products have been identified as a derivative of diketopip-ine. Nonfluorescent diketopiperazines as well as the amines are also abundant.

At pyrolysis temperatures of 700°C the number of component products is iderably reduced. Pyrene is abundant, and other polycyclic hydrocarbons, such nzopyrenes and coronene, are indicated.

It was found that the quantity of fluorescent materials produced in the optimal erature range of pyrolysis for Micrococcus lysodeikticus varies linearly with uantity of starting material over a wide range of concentration.

Analyses will be carried out to identify the 300°C pyrolysis products of amino other than L-leucine, of hydrocarbons and of sugars.

After these reaction mechanisms are understood pyrolysis will be optimized respect to temperature and time to yield maximum conversion to fluorescent atives.

LYSIS OF BIOLOGICAL COMPOUNDS

An attempt was made to detect some of the highly conjugated biological com-ds in soil by solvent extraction followed by fluorometry of the extracts. Sequen-xtractions were used to selectively dissolve different chemical classes of gical compounds.

First the soil was extracted with aqueous growth medium (or water) to yield a nsion containing microorganisms, free and bound aromatic acids, and NADH. nic solvent extraction was used next to remove pigments and lipids. The same

sample was then hydrolyzed with 0.1 N NaOH at 100° for 20 min in order to obtain ribonucleotides. After acidification of the solution with perchloric acid, the fluor cence intensity of the purine nucleotides was read at 390μ with excitation at 285μ. this method, RNA can be determined without difficulty at the nanogram level.

After the RNA determination, the alkaline hydrolysis products and the sam residue were hydrolyzed in N HCl at 100° for 20 min to obtain the purine bases. Adenine and guanine were determined in acid, and guanine also in base. This sen tive fluorescence technique permits quantitative determination of soil microorgani in terms of their nucleic acid base content. The method is sensitive enough to pe estimation of from 10 to several hundred thousand bacteria by quantitative measur ment of their RNA and DNA hydrolysis products.

Analytical methods for nucleic acid bases other than guanine and adenine w be developed either by condensation with specific reagents or by phosphorescence techniques. Study of photosynthetic components will be continued to obtain a clea understanding of the role of photoactive pigments in biological energy conversion systems.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

Publications in the Open Literature

1. Geiger, P., Bauman, A., and Rho, J., "Fluorometric Analysis of General Organics by Pyrolysis," Journal of Organic Chemistry, October 1966.

BIOSCIENCE EXPERIMENT DEVELOPMENT
NASA Work Unit 189-55-02-03-55
JPL 386-51301-2-3260
G. A. Soffen

)BJECTIVE

Studies and laboratory work are performed to develop methods for life etection experiments. The emphasis of the effort is on methodology--its applica- ility and limitations. Scientific breadboards of experiments are constructed and eveloped for use on planetary missions. The current efforts deal largely with ptical and wet chemical methods.

URRENT EFFORTS

During the past six months the manpower for this program has been diverted the Biosatellite program (see NASA Work Unit 189-54-01-04-55). Here the prob- ms dealt with developing reliable miniaturized colorimeters and fluorimeters for t chemical analysis. The components and the optical geometry utilized for the osatellite experiment are appropriate for use in life detection experiments involv- g wet chemical reactions and optical readout.

New laboratory facilities have been assigned in order to implement this fort. The present location is in the same building as the microbiology group and space instruments group, which permits daily liaison. Previously, the effort s performed at an off-lab location which presented communication difficulties.

Analysis of the electronic problems associated with the automated histo- emical microscope has revealed that some rework is necessary. The discriminat- g signal that is used for selecting the "field of interest" operates by a differential cuit that is the output of two photomultipliers. This circuit is noisy, and the urce of this noise is undetermined. It will be necessary to make a careful check of components and of the basic electronic design in order to make this operate. The ics will also require further alignment and adjustment in order to optimize the age resolution.

Some further effort to explore the usefulness of the infrared portion of the ctrum for life detection has indicated the difficulty of the method. Using a micro- ctrophotometer, operating in the 1 to 10μ range, absorption by thin layer of logical material, e.g., serum protein preparation, epithelial layer of leaf eals certain characteristic bands indicative of certain organics, e.g., carbonyl carboxyl. Preliminary experiments with specular reflection of infrared by bio- ical material indicate that using conventional equipment the intensity of radiation not likely to be sufficient.

A brief and successful effort was performed as a special test using an ctro-optical method for detecting and quantitatively measuring microscopic tion. An image dissector tube was coupled to a microscope so that the image was nned perpendicular to the direction of motion. In order to simplify the problem, nidirection image was selected (vascular bed of frog's hind foot). The blood cells he capillaries present an ideal target. Motion was measured with ease in this e and was found to correspond very closely with photographic methods.

PUBLICATIONS DURING FY 1966

Papers presented at meetings and symposia

1. Soffen, G. A., and Sloan, R. K., "Life Detection by Visual Imaging," presente at the 12th Annual American Astronautical Society Meeting, Anaheim, Californ May 24, 1966.

2. Soffen, G. A., "An Automated Approach for Wet Chemical Analysis on a Space Mission," prepared for presentation to the Instrument Society of America, August 4, 1966.

PUBLICATIONS ANTICIPATED FOR NEXT REPORT PERIOD

None.

EXOBIOLOGY INSTRUMENTATION
NASA Work Unit 189-55-02-04-55
JPL No. 386-51401-2-3220

J. R. Clark

BJECTIVE

The long-range objective of this unit is to develop techniques for performing et chemical analyses upon a planetary soil. During FY 1966, two development sks have been pursued: (1) the data handling and sequencing systems for Biosatel-:e as reported in the previous semiannual report, and (2) the solid-state amplifier scribed in this report.

ᴍPLIFIER DEVELOPMENT

This amplifier is for the following applications:

1. To detect calcium and creatine in urine.

2. To use with turbidity measurements in the detection of micro-organisms on a planetary surface.

lcium Detection

Calcium can be detected in urine by exciting a solution of urine and calcium h light energy at 490μ and observing the fluorescent product at 520μ. The light ırce used in the measurement consisted of a voltage regulator driving an incandes-ıt lamp (Pinlite Division, type 60-25). The regulator used to supply lamp voltage good regulating characteristics with a temperature coefficient of 0.001%/°C. To ract the excitation wavelength (490μ), an ultraviolet filter was placed between the ırce and the urine calcium test chamber. The output light part consisted of a en filter to pass only the 520μ light, a yellow filter to sharpen up the bandpass racteristics of the green filter, and a cadmium sulfide detector (Clairex CL902N). sensitivity peaks up at 515μ and is down less than 3 db at 520μ.

atine Detection

Creatine can be detected in the urine by passing monochromatic light centered 85μ through a solution of urine and alkaline picrate. The solution in the presence reatine forms a pink color with a maximum absorption of 485μ. The monochro-ic light is obtained by passing light from an incandescent bulb through corning 5 and 5-61 filters. The monochromatic light passing through the test chamber is in detected with a cadmium sulfide cell. Although the response is down to 25% 485μ) of the value at 515μ, adequate signal is still obtained.

plifier Description

A balanced pair of cadmium sulfide cells form the upper arms of a bridge. bridge output feeds an input differential stop composed of two Siliconix, Inc. 608 field-effect transistors. This device was chosen from zero temperature fficient and next stage coupling considerations. The differential pair drives

directly an integrated circuit operational amplifier. In this application, an Amel type A13-251 was used. The operational amplifier has the following specification

1. MIL temperature range (-55°C to +125°C).
2. DC loop gain (no load) 5000 min.
3. Open loop bandwidth, 10 mHz.
4. Input offset voltage, 5 mv.
5. Input current, 500 na (max).
6. Input offset voltage drift, 50 mv/°C max.
7. Dynamic output range (no load) 18v p-p.
8. Dynamic output range (1 K load) 10v p-p

The output voltage (V_o) has the relationship,

$$V_o = \frac{4VR_b\left(\frac{1}{R_s} - \frac{1}{R_r}\right)}{\frac{R_b}{R_s} + 1}$$

Where R_b is the bridge fixed resistance, V is the bridge supply voltage, R_s is th resistance of the sample cell detector, and R_r is the resistance of the reference detector. See Fig. 1.

Work on this task was suspended in mid-March 1966, and the manpower temporarily diverted to support the complementary Biosatellite Fluorometry Ta (NASA 189-54-01-04-55).

FUTURE WORK

Light-intensity dependence may be eliminated if the circuit measures the ratio of the detector resistances rather than the differences. A circuit to accom plish this function will be developed in FY 1967.

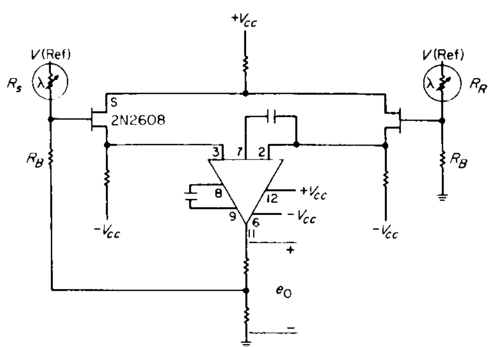


Fig. 1. Amplifier schematics

DETECTION OF LIFE-RELATED COMPOUNDS
NASA Work Unit 189-55-02-08-55*
JPL 386-51201-2-3260

C. H. Stembridge

BJECTIVE

The objective of this work unit is to provide information of use in defining a chnique for detecting the presence of and for analyzing organic compounds in a netary surface. The analytical procedure being developed is based on the comed techniques of gas chromatography and mass spectrometry. The procedure ng followed is: (1) thermal treatment of the sample to yield volatile fragments, separation of these volatiles by gas chromatography, and (3) mass spectrometric ermination of the components present in each gas chromatograph peak. In addin, differential thermal analysis of a surface sample will be performed in both oxiing and reducing atmospheres to detect a disequilibrium between the surface and atmosphere.

GANIC ANALYSIS

The activities of this study are concerned with methods of sample treatment, with the pyrolysis and separation of the pyrolyzates obtained from various pure npounds, soils, and soil extracts.

A study of various possible column packing materials has revealed that opak Q gives the best performance in separating the pyrolysis products which e been obtained. Peak shapes are symmetrical with little or no tailing, and most ortantly the water separation is clean, with no tailing even under severe rloading.

Pyrograms have been obtained from six representative desert soils (from the Cameron collection), the water extract of soil No. 35, N-Acetyl Phenylalanine, ic acid, RNA, mannitol, hypoxanthine, vanillin, and several of the porphyrins, g the new column material. In each case, many more fragments are separated n compared with the previously used column materials. In the case of soils (and extract) about 50 peaks are typically obtained. These results indicate that the of a powerful analytical tool such as the high resolution mass spectrometer is ential.

In a study of the pyrogram of the water extract of soil No. 35, trapping of indial peaks and subsequent transfer to a low resolution slow-scan mass spectromhas allowed identification of acetone, acetonitrile, benzene, and hexene, in the lysis products.

Research currently in progress and planned for the next fiscal year will include udy of heating rates, flow rates, and heat transfer rates in order to determine parameters necessary for breadboard design. It is also planned to analyze soils etermine the organic compounds present prior to pyrolysis and to continue the y of the thermal treatment of pure organic compounds as well as soils (both raw enriched with chosen pure organics). The identification of the pyrolysis products

ntly funded under NASA Work Unit 185-37-26-09-55.

will be performed by the gas chromatograph-high resolution mass spectrometer combination. It appears that this type of research will be necessary for several more years before we will become confident of our ability to infer the compounds originally present in a soil prior to the pyrolysis treatment. It is felt, however, th before the end of FY 1967 sufficient knowledge about the necessary pyrolysis conditions and types of volatile fragments given off will be obtained to allow the design o scientific breadboard for the organic analysis experiment.

HIGH RESOLUTION MASS SPECTROMETER

The high resolution mass spectrometer and multichannel tape recorder have been received. A laboratory system has been constructed consisting of an experimental pyrolysis furnace, gas chromatograph, carrier gas separators, mass spectrometer, and tape recorder. A computer program for producing element maps from the digitized tape data has been obtained from S. R. Lipsky of Yale Universit and is being modified to make it compatible with our computing facilities.

Research planned includes identification of the pyrolysis products of the org analysis study, the accumulation of a library of data tapes, and the development o computerized data analysis techniques.

DTA STUDIES

As part of the research under this program, the following results have been obtained. Thermograms of the 18 natural amino acids have been obtained in He a in air. The thermal stability of Poropak has been studied, resulting in a higher column operating temperature on our laboratory gas chromatographs. A study of sulfide reactions has indicated that they may be separated from organic decompos reactions on the basis of reaction characteristics in He and in air. Anhydrous re studies have shown that the determination is feasible only if a quantitative water detector is located in the effluent gas stream. DTA studies have begun on desert soils in He and in air. Organic constituents are detectable if present above trace amounts.

Plans for the next fiscal year include studies of the H_2 reactions of organic sulfides, and desert soils. The design and construction of a scientific breadboar for the DTA experiment will begin in the third quarter of FY 1967.

PUBLICATIONS DURING FY 1966

<u>Papers presented at meetings and symposia</u>

1. Bollin, E. M., "Differential Gravimetric Hypsometry," presented at the Advanced Session, Thermoanalysis Institute, Fairleigh Dickinson Universi Madison, New Jersey, June 22, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

DESERT MICROFLORA
NASA Work Unit 189-55-04-01-55
JPL 386-50301-1-3260
R. E. Cameron

ECTIVE

The primary objective of this program is to determine the influence of ironmental factors on the ecology of soil microbiota as related to planetary oration for life. Secondary objectives include determinations of the distribution nicroorganisms within a volume and area of soil, the abundance of detectable ılations, and a detailed study of the morphology and physiology of basic groups of roflora in desert soils. For the current fiscal year the objective is to determine distribution, abundance, and characteristics of microflora in the Chile Atacama ert and ice-free dry valleys of Antarctica.

e Atacama Desert Soil Samples

Physical, chemical, and microbiological analyses were completed on three soil ples obtained from one soil site. Detailed microbiological analyses were perned. The most abundant groups of microflora were chemoautotrophic bacterial and streptomycetes which grew most abundantly in a neutralized acid soil act prepared from the corresponding Chile soil sample or in synthesized media aining sulfates. Compared to results obtained from southwestern U.S. desert , there were more chromogenic colonies, very few heterotrophes, few or no , anaerobes, or fungi, and a much longer incubation time was generally neces- before colonies could be observed and counted.

A total of 36 additional samples from 22 sites have been collected from the nern Chile Atacama Desert from elevations near sea level to 20,200 ft. These r samples are being processed for analytical and research purposes.

ern Sahara Desert Soil Samples

Physical, chemical, and microbiological analyses have been completed for 7 les obtained from 4 sites in the Sahara Desert. Routine plate counts and dilution res were lower than for those obtained for southwestern U.S. desert soils. dance of anaerobic bacteria and algae were either low or nil. In the 3 sites e samples were obtained from the surface 1-in. and underlying 1- to 6-in. depth, was frequently a higher abundance of microflora at the 1 to 6-in. depth. No e coliforms were present, although small fragments of straw or dung were noted o of the samples. As noted in previous investigations of desert soils, even h fecal matter may be present, viable coliforms are rarely encountered.

ctic Field Trip

Preparations are under way for investigations in several dry valley areas dure coming austral summer in Antarctica. Soil samples will be collected at surnd subsurface levels, and some environmental and sample analyses will be rmed in Antarctica. Samples will be returned to JPL for additional analyses and rch purposes. A two-day symposium provided valuable technical information ntarctic investigations.

Contracts

Cultural and identification studies of desert bacterial and streptomycete isola have been continued under Contract 950783, with Prof. Walter Bollen as principal investigator, at Oregon State University, Corvallis, Oregon. A detailed report ha been received on 24 isolants from the Eastern Egyptian Sahara Desert. Most of th isolants were Bacillus sp. or undescribed new species of soil diptheroids similar t those we have previously isolated from desert soils. A total of 49 additional isola from three samples of Chile Atacama desert soils have been sent for study.

A contract is to be awarded beginning July 1966 for a study of isolaticn meth and identification of fungi from desert soils. The amount of $6000 for a year's st will be awarded to the Department of Biology, New Mexico State University, Las Cruces, New Mexico. Dr. Eugene Staffeldt will be the principal investigator.

PUBLICATIONS DURING FY 1966

Publications in the Open Literature

1. Cameron, R. E., "Properties of Desert Soils," In Pittendrigh, C. S., et a "Biology and the Exploration of Mars," chapter 8, pp. 164-186, National Academy of Sciences National Research Council, Washington, D.C., 1966.

2. Cameron, R. E., "Soil Sampling Parameters for Extraterrestrial Life Det tion," Journal Arizona Academy of Science, Vol. 4, pp. 3-27, March 1966.

JPL SPS Contributions

1. Cameron, R. E., and Blank, G. B., "Soil Studies - Microflora of Desert Regions. VIII. Distribution and Abundance of Desert Microflora," SPS No. 37-34, Vol. IV, pp. 193-202, Aug. 31, 1965.

2. Cameron, R. E., Odd, C. W., and Britton, H. E., "Soil Studies - Desert Microflora. IX. Measurement of Soil Moisture Suction by Thermal Condu tivity Probes," SPS No. 37-35, Vol. IV, pp. 209-215, Oct. 31, 1965.

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4. Cameron, R. E., and Blank, G. B., "Soil Studies - Desert Microflora. X Desert Soil Algae Survival at Extremely Low Temperatures," SPS No. 37- Vol. IV, pp. 174-181, Feb. 28, 1966.

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Bollen, W. B., "Microorganism Study on Isolants from Sahara Desert" (includes supplemental progress report of March 15, 1966), Oregon State University, Corvallis, Oregon, Report No. 3, April 1, 1966 (JPL Contract No. 950783).

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Cameron, R. E., and Blank, G. B., "Desert Soil and Algae Response at Extremely Low Temperatures," Cryogenic Technology. In Press.

Bauman, A. J., and Cameron, R. E., "Detection of Phthalate Esters as Contaminants of Lipid Extracts from Soil Samples," Journal of the American Oil Chemists' Society (in Press).

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Technical Reports

Cameron, R. E., and Blank, G. B., Desert Algae: Soil Crusts and Diaphanous Substrata as Algal Habitats, TR 32-971, July 15, 1966 (in Press).

Cameron, R. E., Blank, G. B., and Gensel, D. R., Desert Soil Collection at the JPL Soil Science Laboratory, TR 32-977 (in Press).

Cameron, R. E., Blank, G. B., and Gensel, D. R., Soil Properties of Samples from the Eastern Sahara Desert (to be JPL TR; all data complete).

Technical Memorandum

Cameron, R. E., Blank, G. B., and Gensel, D. R., Tests, Measurements, and Properties for Desert Soils (to be JPL TM; first rough draft of manuscript completed).

BIOSAMPLING

NASA Work Unit 189-55-04-02-55
JPL 386-50401-2-3260; 386-50402-2-3220
G. A. Soffen
J. L. Stuart

BJECTIVE

The problem of acquiring a planetary surface sample by a landed vehicle is ticipated as one of the more difficult tasks to be performed. This effort is a pre- minary examination of the technological and engineering problems and a test of me simple ideas.

ENERAL PROGRAM

Most of the effort was the direction of two out-of-house contracts. One was to tton Systems, Inc., and the other to the University of Rochester.

A contract was completed with the Applied Science Division of Litton Systems, ., for the "Design and Development of an Air-ejector Powered Pneumatic Surface mpling System" (Contract 950771). This was directed towards the development of imple device for possible use in collecting a sample on an early Mars landing ssion.

A pneumatic sampling system was developed and tested under simulated Mars ironmental conditions. The unit relies upon a method of air blast dislodgment of rface particles by an external traversing sampler head using a high-velocity air eam. Transport of the particulate to the main sampler body is performed pneu- tically. A study was made to distinguish between horizontal and vertical transport. moval of the sample is carried out by centrifugation using a cyclone separator. device is capable of operation with particles as large as 800 μ diameter at bient pressures as low as 5 millibars. In tests with sandy soil, the collection rate his device is of the order of 15 grams/min for periods of up to 10 min. Biological luation indicates that the acquired sample is representative of the environment n which it was taken.

A contract was initiated with the University of Rochester, Dr. C. R. Weston, "A study of the Relation of Surface Sampling and the Environmental Distribution of anisms" (JPL Contract 951321).

This effort is primarily aimed at optimizing any sampling device for biological nples. The results should be useful in designing or improving samplers, and pro- s the biological rationale for inputs to the mechanical designer. The study resses itself to four questions.

1. Are microorganisms characteristically associated with a particular range of soil particle size?

2. Is the association between particles and organisms the same for various distinct soil types?

3. Do soil organisms typically occur in aggregates (which might be selectively sampled)?

4. Are the organisms in the dust collected from a solid surface representative of the microflora of the parent soil?

The approach is to select samples from sand, loam, and clay, separate by s and assay each portion for its bacterial population by growth test and direct micro- scopic observation. This will be used to correlate population to surface area, colo formation, particle size, and mean colony size.

The present progress in the contract is essentially the development of the methodology and performance of the laborious counting task.

This work unit has been terminated and the responsibility has been transferr to Mr. George Hotz (JPL Section 322) who will be developing the sampling progran on a broader scale on a separate work unit.

PUBLICATIONS DURING FY 1966

Papers presented at meetings and symposia

1. Stuart, J. L., "Sample Acquisition for Life Detection Experiments," Ameri Astronautical Society, 12th Annual Meeting, May 24, 1966.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

JPL Technical Memorandum No. 33-296, Vol. I

PLANETARY QUARANTINE STERILIZATION (189-58)

DEVELOPMENT OF A BIOLOGICAL INDICATOR FOR DRY HEAT STERILIZATION

NASA Work Unit 189-58-00-06-55 (FY 1964)
JPL 386-55806-2-2945

A. S. Irons

JECTIVE

The purpose of this study was to develop a reliable biological test system which ld be used in conjunction with space hardware to indicate whether or not sterility achieved as the result of a specified dry heat sterilization procedure. For the pose of this study the following conditions were considered as the dry heat sterili-on cycle: 135°C for 24 hr in an atmosphere of dry nitrogen.

TIVITIES AND RESULTS

A survey of plastics, insulating materials, silicones, and ceramics to be used he carrier for the test organism was completed, resulting in the selection, pro-ement, and laboratory evaluation of types having properties necessary for the per fabrication, handling, and stability of the indicator at 135°C. It was demon-ted that a biological indicator made up of a spore powder tablet and a Teflon car- could be produced which would remain viable after exposure, to a temperature 35°C for a period of up to 20 hr but the majority of the indicators are rendered ile in much less time than this; i. e., 61% of the indicators subjected to 135°C e sterilized at times ranging from 4 to 18 hr; 33% survived for 18 hr and 6% ved organism survival for 20 hr. The erratic survival pattern which existed dur-he study was considered the result of preparing the spore powder tablets from y different spore crops, grown, harvested and processed under varying condi-s. The development of new procedures and techniques was responsible for the rent spore crops.

Work was discontinued on this study because of lack of funds to complete the inal contract and an interim final report was issued by the contractor. After a ough study of this report, it was decided to fund an extension of the contract. tional funds were approved and allocated and a work statement was prepared. re any procurement action was initiated some questions arose as to the exact nd applicability of the indicator. This, plus the question of whether or not the lated cycle was too stringent, caused a delay in this study until the problems d be more clearly defined.

Recently, the NASA Spacecraft Sterilization Advisory Committee recommended this study should be terminated.

MARY

An attempt was made to develop a biological indicator and test system which d be used to determine the adequacy of the proposed dry heat sterilization cycle. indicator was to be used on other than flight equipment and verification of lity of the actual flight hardware was to have been by implication, i. e., the indi- was to be used to produce biological evidence of process efficiency.

A spore powder tablet was developed which approached the required heat resistance but an erratic survival pattern was noted. The limited investigation in this area did not uncover the exact cause of the erratic behavior but it was felt that this disparity was the result of a nonuniform population containing organisms with different "D" values. The nonuniform population was a result of the development of methods of growing, harvesting, cleaning, and freeze drying the spores used to ma[illegible] the indicator tablet.

The Spacecraft Sterilization Committee disagreed with the concept of compressed tablets made entirely of spores and recommended that a different concept f[illegible] indicators was more desirable. This study has been discontinued.

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

1. Irons, Alexander S., "Development of a Biological Indicator for Dry Heat Sterilization," presented at 1st National Conference on Spacecraft Sterilizati[illegible] Pasadena, California, November 1965.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

STERILE ASSEMBLY TECHNIQUES
NASA Work Unit 189-58-21-01-55
JPL 386-82201-2-2945
J. J. McDade

JECTIVE

The objective of this work unit is to investigate and develop techniques and cedures which will reliably prevent contamination of sterile parts and materials ing assembly of spacecraft subsystems or systems.

TIVITIES

During April 1966 the final statement of work, procurement requisition, and e source justification were completed for a continuation study of sterile assembly niques by the Lockheed Missiles and Space Company, Sunnyvale, California.

At the advice of Mr. Paul LePage, Voyager Procurement, it was suggested that gle-source procurement for this task with Lockheed be justified on the basis of a cal continuation effort. However, the original contract has been closed out and gle-source continuation with Lockheed is now impossible. Mr. LePage helped McDade prepare a procurement package for competitive solicitation, the details hich have been reviewed and signed off by all necessary JPL Section 294 sonnel.

Briefly, the contractor shall be required to conduct the study over a 6- to 7-mo od. Design goals of the study include:

1. A statistical evaluation of the efficiency and reliability of microbial barrier (both rigid and flexible) systems for use in spacecraft hardware sterile assembly or sterile repair operations.

2. Definition of microbial and gas challenge tests to support item 1 above.

3. Definition of the sterilization processes for all materials, equipment and hardware required to be sterile.

4. Definition of the packaging process to maintain sterility of items assembled or repaired under sterile conditions.

5. All raw data collected during the study plus the following support documentation:

   a. Monthly Progress Reports.

   b. Mid-term oral report.

   c. Final oral report.

   d. Final written report.

6. Additional supplemental material developed by the JPL cognizant scientist shall include:

   a. Mid-term SPS progress report.

   b. Final SPS progress report.

   c. Possible JPL Technical Report.

   d. Possible manuscript for outside publication.

PUBLICATIONS DURING FY 1966

JPL SPS Contributions

McDade, J. J., and Magistrale, V. J., "Experimental Study of Sterile Assembly Techniques, Final Report," SPS No. 37-34, Vol. IV.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

REVIEW OF HEAT AND ETO SPECIFICATIONS

NASA Work Unit 189-58-21-02-55
JPL 386-82301-2-2945
J. J. Iandolo
A. S. Irons

3JECTIVE

To perform research on the dry heat resistance of selected microorganisms, d to provide practical procedures for decontamination of planetary spacecraft with ıylene oxide, in support of the definition of dry heat and ETO spacecraft sterilizan specifications.

Y HEAT STUDY - J. J. Iandolo

Earlier I supported Dr. R. Angelotti of the R. A. Taft Sanitary Engineering nter in determining the dry heat resistance of B. subtilis var. niger. I specifically estigated the effects of nonpolar solvents on the thermal resistance of this orgam. These data are presented in Table 1.

Table 1. Thermal resistance data

Suspending medium	D_{125} (min) after storage at 3C			
	0 hr	5 hr	18 hr	168 hr
Water suspension	12.7	---	---	13.0
Acetone suspension	12.7	11.7	6.5	5.5

As can be clearly seen, suspension of spores in acetone for periods of 5 hr or ıter drastically reduced the D_{125} value. After 18 hr the D value was essentially that of the water suspension. This demonstrated that acetone and probably other polar solvents are not recommended for storage of stock cultures of B. subtilis niger.

Further investigations discounted the use of stainless steel strips as a supportmedium for dry heat work. Due to the heat, the spores were fixed onto the ps and virtually impossible to remove, even if viable. Therefore a new system devised utilizing a non aqueous solvent diethyleneglycol as a support. This erially improved sampling characteristics since it was liquid and pipettable.

A clean spore preparation of Bacillus subtilis strain 5230 was prepared. This ınism was first identified by Dr. Clarence Schmidt of Continental Can Company. ry heat resistance has been extensively studied by Dr. Irving Pflug of Michigan

State University. A heavy, clean spore preparation was effectively obtained and stored. The heat resistance has been surveyed at 125°C in the diethylene glycol apparatus and the data compared favorably with that obtained with B. subtilis var. niger. However, all the D values determined thus far are significantly lower than that reported by other workers. In this regard it is my opinion that the supporting menstruum (DEG) may be hydrolysing to ethylene glycol, which is toxic, or perhap other factors such as osmotic pressure may be responsible for the lowered heat resistance. Some work should be directed towards resolving this problem before t DEG system is discarded.

Additionally, other non-aqueous solvents should be studied such as 1, 5 pentanediol. This compound and others like it have a lower osmotic pressure and may produce more favorable results.

As a side light of this project, the heat treatment given to electronic piece parts as part of the normal JPL screening procedure was investigated. These dat based on the original heat treatment of D_{135} = 1.8 hr,are presented in Table 2. I clear that even with this severe treatment most parts receive adequate thermal exposure to kill the existing organisms.

ETHELENE OXIDE STUDY - A. S. Irons

Introduction

An examination and review of existing ethylene oxide specifications was necessary because of the issuance of engineering requirements calling for exposu to more stringent conditions for all space hardware having to meet type approval flight acceptance specifications. These specifications call for an increase in tim temperature, relative humidity, ethylene oxide concentration, and a rate of appli tion above that stipulated in the Ethylene Oxide Compatibility Specification, which been the JPL working document up to the present time. In addition, the requirem imposed by the Sterile Assembly Development Laboratory (SADL) facility have ca for further revisions in the original specification.

Objectives

The objectives of the review and examination were (1) to determine the revi necessary to develop an ETO cycle which would insure compatibility with the spe cation which was issued for TA and FA testing of capsule system elements, and (develop an ETO cycle which will be compatible with the sterilization and deconta tion chambers which will be located within the proposed facilities, as well as to develop a more effective ETO cycle, one which will sterilize more consistently.

Accomplishments to Date

As a result of the review, a new method of application of ETO humidity and temperature has been developed which will be used in conjunction with the SADL chamber.

The size and configuration of contemplated space hardware, the sterilizati and decontamination constraints and the decontamination requirements of subsys and assemblies have introduced problems which directly affect the process and t equipment which can be used to sterilize parts. This is especially true when a

aseous sterilant such as ethylene oxide is used. When an attempt is made to terilize space hardware with ethylene oxide two major problem areas arise: (1) the rge size of the spacecraft and (2) the condition of the microorganisms residing on e space hardware, when it is subjected to the gaseous sterilant.

The chamber required to house the spacecraft during exposure to ethylene oxide easures 18 x 18 x 18 ft and has a capacity of 6,000 ft^3. The size of the chamber d the mass and heterogeneity of the craft itself present problems not previously countered. The problems of major concern are as follows:

1. The method of heating a chamber of such a large volume.
2. The method of heating a load of such a large mass.
3. The prevention of condensation on cold parts when moisture is introduced.
4. Control of humidity within the chamber and in close proximity to the load.
5. Prevention of stratification of gas and moisture.
6. Prevention of polymerization of ethylene oxide.
7. The most efficient method of hydrating the desiccated spores found on space hardware.
8. Precise control of humidity, temperature, and ethylene oxide concentration.

During assembly and test, space hardware is subjected to a vacuum in the ge of 10^{-6} torr for up to 2.5 wk (1 torr = 1 mm Hg absolute pressure) and then jected to ambient conditions for a period of from 3 to 4 mo. The conditions to ch the organisms on the space hardware are subjected during this period can se extreme dehydration of the cells, which in turn can prevent sterilization by lene oxide.

A process has been developed for the use of ethylene oxide in the large chamber ch will solve the problems of major concern, and will permit maximum rehydra- of desiccated cells.

A work statement has been prepared which calls for a comparative evaluation thylene oxide cycles. The work statement is now part of the Procurement Pack- now being processed by Procurement. It is expected that the Request for posals will be sent to qualified vendors sometime before the first week in July.

ire Activities Planned

After receipt and review of the vendors proposals the company that most nearly ts our criteria of performance and price and is considered to be the most ble, will be awarded a CPFF contract.

This task will require approximately 48 wk to complete.

It is expected that work will be initiated during the first quarter of FY 1967.

PUBLICATIONS DURING FY 1966.

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

Table 2. Heat treatment data

Family	Type	Specification		Temperature, °C	Time, hr	D values traversed	Load estimate	Remarks
		General	D.S.					
Capacitors	Ceramic	ZPH-2244	0804	125	250	57	10-1000	Sealing also 125°C for 250 hr
Capacitors	Glass	ZPH-2244	0802	125	250	57	10-1000	Sealing also 125°C for 250 hr
Capacitors	Paper	ZPH-2244	0800	125	250	57	10-1000	Sealing also 125°C for 250 hr
Capacitors	Tantalum	ZPH-2244	0801	125	250	57	10-1000	Wet foil
Capacitors	Ceramic	ZPP-2744	2502	125	168	38	10-1000	----------
Capacitors	Ceramic	ZPP-2744	2503	85	168	1.0	10-1000	Insufficient heat treatment
Capacitors	Ceramic	ZPP-2744	2530	85	168	1.0	10-1000	Insufficient heat treatment
Capacitors	Ceramic	ZPP-2744	2527	125	168	38	10-1000	Feed through style
Capacitors	Ceramic	ZPP-2744	2528	125	168	38	10-1000	Stand off style
Capacitors	Mylar	ZPP-2744	2515	85	168	1.0	10-1000	Insufficient heat treatment
Capacitors	Mylar	ZPP-2744	2508	125	168	38	10-1000	
Capacitors	Porcelain	ZPP-2744	2511	125	168	38	10-1000	Sealing operation
Capacitors	Porcelain	ZPP-2744	2511	125	168	38	10-1000	Storage
Capacitors	Porcelain	ZPP-2744	2514	125	168	38	10-1000	Sealing operation
Capacitors	Porcelain	ZPP-2744	2514	125	168	38	10-1000	Storage
Capacitors	Tantalum	ZPP-2744	2501	85	168	1.0	10-1000	Solid insufficient heat
Capacitors	Tantalum	ZPP-2744	2507	85	168	1.0	10-1000	Wet foil insufficient heat
Capacitors	Tantalum	ZPP-2744	2525	85	168	1.0	10-1000	Wet foil insufficient heat
Diodes	Control Rect.	ZPH-2252	All	150	168	365	N/A	----------
Diodes	General	ZPH-2246	All	175	168	3360	N/A	----------
Diodes	General	ZPP-2746	All	175	168	3360	N/A	----------
Inductors	R.F.	ZPP-2738	All	100	168	4(9.5)	10^3-10^4	Heat shock 2.5 hr at 150°C

Table 2. Heat treatment data (cont'd)

Family	Type	Specification		Temperature, °C	Time, hr	D values traversed	Load estimate	Remarks
		General	D.S.					
Microcircuits	General	ZPP-2750	All	125	250	57	N/A	----------
Resistors	Fixed	ZPP-2748	All	145	250	342	0-10	----------
Resistors	Variable	ZPP-2749	All	N/A	N/A	---	0-10	----------
Transformers	General	ZPP-2737	All	100	168	4(9.5)	10^4-10^5	2.5 hr at 150°C
Transistors	General	ZPH-2251	All	200	168	33600	---	----------
Transistors	Unijunction	ZPP-2751	7037	175	168	3360	---	----------
Transistors	General	ZPP-2751	All	200	168	33600	---	----------
Thermistors	General	N/A	N/A	300+	2	4,000,000	---	Sealing operation

PRESTERILIZATION CLEANING OF SPACECRAFT PARTS

NASA Work Unit 189-58-21-03-55
JPL 386-82401-2-2945

A. S. Irons

BJECTIVE

The objective of this study is to establish standard methods of cleaning acecraft parts, subsystems, and systems and to determine the effectiveness of ese methods in reducing their microbial load.

TRODUCTION

When heat is used as the medium to sterilize any given material the number of croorganisms associated with the material influence the time and temperature quired to sterilize it. As the number of microorganisms is reduced, the time l/or temperature required to sterilize is also reduced. And as the time and/or nperature required to sterilize is reduced, the deleterious effects of the procedure e generally reduced, thereby decreasing the possible reliability degradation of rts subjected to the procedure. With this in mind one can see the obvious advan-es of reducing the number of microorganisms associated with space hardware.

When chemical agents are used as the medium to decontaminate or attempt to rilize any given material, the number of microorganisms associated with the terial influences the time of exposure to the chemical agent and the concentration strength of the agent.

The microbial load affects all other methods of sterilization or decontamina-n as well by affecting the effort required to sterilize.

dy Approach

The study was designed to:

1. Survey presently available sporicides, germicides, disinfectants, antiseptics, sanitizing agents, fungicides, chemicals, detergents, and cleaning compounds as well as microbiocidal lubricants and greases and attempt to determine by experimentation the microbiocidal effectiveness of these compounds.

2. Establish and recommend standard methods of use of the surveyed compounds.

3. Permit the generation of a list of approved chemical compounds which could be used to clean and decontaminate spacecraft parts, tools, and assembly areas. Candidates for this list were such compounds as peracetic acid for decontamination and the fluorocarbons for cleaning.

4. Also, consideration was to be given to such physical adjuncts as ultrasonics alone and in conjunction with various chemical compounds.

ACTIVITIES DURING REPORT PERIOD

A survey was started to develop a tentative list of potential cleaning and disinfecting agents to be included in the work statement for this study and to determine the extent of present efforts by industry or aerospace which require the same similar methods and compounds.

The surveys called for further investigation which led to the conclusion that compatibility studies would be required of all proposed cleaning and decontaminati agents and all space hardware coming in contact with them.

Funding of such compatibility studies was not considered because of the exte sive and complex testing program which would be required to yield significant dat

This study was cancelled, because the magnitude of the program made it fi cially impractical.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

MICROBIOLOGICAL FILTERS - LIQUID AND GAS

NASA Work Unit 189-58-21-04-55
JPL 386-80301-2-2945

A. S. Irons

JECTIVE

Studies conducted by independent laboratories indicate that the claims made for efficiency and dependability of some liquid and gas filters have been highly ggerated. This has been a source of concern because of the critical requirements pace hardware. The filter study is designed to evaluate the efficiency and relia-ty of currently available filters to sterilize liquids and gases. The results of this y will provide the basis for selection of filters acceptable for use in the assembly pace hardware required to be clean or sterile. (See JPL SPS 37-29, Vol. IV - aluation of Microbiological Filters for Liquids and Gases," by A. S. Irons.)

RODUCTION

Production of certain space hardware, portions of the dry heat sterilization e, biological experiments, and maintenance of a sterile spacecraft after terminal ilization, require sterile filtration. For example some liquids required for bio-cal experiments, certain liquid propellants and battery electrolyte, represent a of the substances that may be degraded by dry heat and/or chemical sterilization may therefore require sterilization by filtration. Also, areas such as spacecraft mbly areas, glove box systems, and environmentally controlled areas housing ecraft immediately prior to launch, have requirements for sterile gases. Con-and conditioning equipment used to deliver sterile gas to these areas will have to incorporated in their systems, one or more filters capable of removing all of nicroorganisms which may be entrained in the gases. Gases carried aboard ecraft, such as the nitrogen used in some altitude control devices, may also have tion requirements. In addition, the sterility testing of filtered liquids or gases portant in the monitoring of sterilization procedures. Any assaying procedures be capable of detecting small numbers of microorganisms in large volumes of ds and gases.

OMPLISHMENTS TO DATE

Hepa Filters

High efficiency particulate air filters were tested by challenging them with an sol of viable particles. Efficiency was determined by counting the number of nisms collected by air samplers located in the test duct on the downstream side e filter.

Calculations indicated a viable particle challenge of 250,000/min. The sampler es were designed to be isokinetic for the duct used. Linear velocity profiles s the face of the various filters ranged from zero to over 900 ft/min due to tions in filter media and lack of homogeneity. Filter efficiencies based on the er of challenge organisms upstream of the filter versus the number downstream e filter ranged from 99.9736% to 99.9999%. The size range of the viable par-s used made it necessary for the filters to be at least 99.99+% efficient, using ystem, before they could be considered acceptable. Only two (2) of the seven (7)

groups of filters tested had zero rejections. Within the other five (5) groups, rejections on the basis of failure to meet the efficiency requirements ranged from 0 - 75%.

B. Membrane Filters

Membrane filters are used for the filtration of liquids and gases in small volumes and are generally more reliable than depth filters but there seems to be little correlation between designated pore size and filter efficiency or reliability. One would expect that the smaller pore sizes would be more efficient and that pore sizes of 0.25 μ or less would effectively remove organisms of the size of Serratia marcescens which was used as the challenge organism, but this was not found to b the case. It was concluded that membrane depth filters are unreliable as are mem brane filters of small pore size, but some of these results are considered suspect and will be investigated further. These tests so far indicate little or no correlatio between designated pore size and filter efficiency. Of the filters tested, ranging i pore size from 0.45 to 0.20 μ, 20% failed to remove 100% of the organisms contai in the media being filtered and were rated unsatisfactory.

The data generated during the period of performance cover 2 major filter ty the high efficiency low pressure air filters and the liquid filters of membrane con struction. Two categories of the four originally proposed remain to be initially investigated; they are evaluation of filters in a pressure gas-flow system and eval tion of filters in a pressurized liquid-flow system. Some work remains to be don the other two categories mentioned.

Work was discontinued on this study because of lack of funds to complete th original contract. Although a technical evaluation of the interim final report issu under this contract indicated satisfactory performance of the work accomplished, much of the effort required for satisfactory completion of the study remained to b expended. Work was terminated before completion of the study when the funds allocated under the contract were exhausted.

Evaluation by the cognizant engineer and procurement negotiator indicated the contractor could not have possibly completed this CPFF contract with the fun allocated because of the techniques which had to be developed and the testing equi ment which had to be designed and fabricated.

Evaluation of the data generated during the study led to the decision to issu new contract for completion of the study using the techniques and equipment deve oped. Additional funds were approved, a work statement was prepared and a fix price contract is being awarded to Wilmot Castle which spells out the additions a modifications considered necessary because of the findings under the original contract.

The contract has been negotiated and it is anticipated that work will be star during July. Before work can be initiated under the new contract the previous c tract must be closed out. It is anticipated that this will occur during the first pa July.

FUTURE ACTIVITIES PLANNED

Further work will include the following:

1. Investigation of the cause of liquid filter failure. This will include examination of filter holders as well as filter media and will involve the use of more than the one organism originally proposed.

2. Evaluation of additional liquid or high pressure gas filters which have been developed since the initiation of this study. This includes filters which may have a bacteriostatic effect and which will require special culturing techniques.

3. Determination of the efficiency of liquid filters placed in tandem.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

MICROBIOLOGICAL LOAD ESTIMATES FOR ELECTRONIC PART SURFACES

NASA Work Unit 189-58-22-01-55
JPL 386-81401-1-2945

J. J. Iandolo

3JECTIVE

Since revision of the original task which was designed to study methods for the covery of sublethally damaged microorganisms, the objective of this study has been determine the numbers and kinds of microorganisms that exist of electronic piece ts and to provide an "in use" test of the procedural manipulations involved in the lysis.

TIVITIES

A procurement requisition and a work statement were prepared and approxi- ely 38,000 was allocated for the 6-mo duration of the proposed contract. work statement was distributed to 10 potential bidders and six positive responses e obtained. After careful technical review it was determined that AVCO Corpora- had the best background for a successful exercise of the task. In addition, their t proposal was in accord with that allocated for the proposed study.

The procurement division has subsequently awarded them the contract, through r agent Mr. Richard Bartlett and at the present time are in the process of obtain- final sign off. The AVCO Corporation is presently collecting the materials to in microbiological assay.

The parts chosen for this study were selected from interim lists of heat ilizable electronic components and polymeric materials. Among those to be ed are: capacitors, diodes, fuses, potting boots, chokes, inductors, relays, stors, switches, thermistors, transistors, transformers, epoxy materials, ones, and other plastics. Analysis of each part type will be with slight modifi- on of the procedures stated in the NASA document entitled "Standard Procedures he Microbiological Examination of Space Hardware." The initial sampling edure will consist of assaying 100 parts of each component type. Although this edure is not statistically elegant it will provide enough information to determine d distributions from which statistical inferences can be drawn.

At a later date various modifications of the handling and quarantine may be osed so that several conditions of storage and fabrication handling can be ılated.

LICATIONS DURING FY 1966

None.

LICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

MICROBIOLOGICAL EXAMINATION OF SPACECRAFT PARTS/INTERIORS
NASA Work Unit 189-58-22-02-55
JPL 386-81901-2-2945
J. J. Iandolo

OBJECTIVE

The objective of this work unit is to determine quantitatively the amount of microbiological contamination in the interior of spacecraft parts required to be sterile.

PULVERIZATION

Pulverization of Solids

The effectiveness of pulverizing epoxy, furane, and other types of resins, prepared with varying amounts of catalysts, has been studied. The physical properties of these resins vary considerably depending upon the amount of hardener used. Those requiring large quantities are rigid and brittle, while those prepared with small quantities have flexible characteristics. The latter type plastic pulverizes in the form of continuous ribbons. While the efficiency of this pulverization is high, the particles are of sufficient size to interfere with the observation of growing colonies. Supplemental pulverization methods may be necessary to reduce the particle size of the latter type plastic to the point where it does not interfere with growth detection.

Circular jeweler saws have been studied and to date do not appear promising. The types of blades which we have employed include tungsten carbide, carbon steel, and stainless steel. These blades have 30 teeth/in. and resemble the conformation of the hack-saw-type blade except for the circular shape. The kerf produced by this type of blade, however, is of smaller width than that produced by the hack saw blade. The principal problem in evaluating these blades is the chipping and flaking of large pieces of plastic from the sample being sawed.

Supplemental Pulverization Procedures

Sonic and ultrasonic energy applied to the pulverized solid appears to result in more efficient recovery of spores. Conditions for the supplemental step with and without the use of a pregrinding phase with the mortar and pestle are optimized. The mortar and pestle permit the fragmentation of the thin ribbons into a finer state. There is no appreciable increased recovery when this step is utilized if the numbers of spores in the plastic are below 100 per gram. However, as the number of organisms per gram increase, the statistical probability of several organisms residing in sufficient proximity to appear as a single colony increase. It is largely for this reason that additional pulverization with the mortar and pestle is required.

With the transducer system available in this laboratory, the optimum results may be achieved following the application of ultrasonic energy for a period of 5 min. Beyond this period of time, a slow decrease in recovery is observed. This decreased recovery does not exceed 20% of the maximum for a period of at least 10 min after which recoveries decrease approximately linearly with time.

NEUTRALIZATION

The neutralization of constituents of the hardener preparation used in the fabrication of plastics is continuing. In the epoxy plastic group, the most commonly used hardener is epichlorhydrin. The most effective techniques devised for neutralizing this compound involve incubation with metabolites possessing functional groups capable of chemical interaction with the epichlorhydrin. Examples of these include histidine, proteins containing histidine, nucleic acids, and certain types of sylfhydryl groups. Although RNA is useful in the inactivation of epichlorhydrin, it, or a contaminating substance present in the preparation used, slightly inhibits the rate of growth when used in high concentrations. We have examined other lots of RNA and inexpensive semipurified lots of DNA in order to determine whether nucleic acids alone would be effective in neutralizing epichlorhydrin.

This toxic compound has been successfully neutralized using a variety of substances including:

1. Incubation at low pH.
2. Incubation with histidine.
3. Incubation with DNA.
4. Incubation with RNA.
5. Incubation with thiolated gelatin.
6. Incubation with various proteins and peptones.
7. Incubation with various combinations of the above.

The pKa of the reactive groups most effective in the neutralization of epichlorhydrin is below 8.5. These include various heterocyclic nitrogens in the purines and pyrimidines of nucleic acids and of histidine and tryptophane (amino acids).

Following the development of the most effective techniques for neutralization epichlorhydrin, they will be applied to the recovery technique for the assay of micr organisms in solid materials.

The neutralization of Epon and Ecco-coat plastics has only been partially successful using the methods which were shown to be effective with Epoxy plastics. The presence of growth inhibitors in these two plastics have been demonstrated in both the hardener and aqueous extracts of plastics which have undergone pulverization. The inhibitory effect of the hardener appears to be due to the same ingredient as those obtained from the aqueous extracts. Thus, it does not appear that these inhibitors are likely to be due to interaction between the hardener solution and the nonpolymerized plastic. Only a portion of the growth inhibition induced by the constituents of the hardeners used in these two types of plastics was reversed by the u of RNA-beef extract neutralizer which had been so successful with Stycast. We investigated the use of a wider variety of neutralizers in an effort to increase the recovery of spores from these plastics. The preliminary experiments conducted

vith high concentrations of RNA digests indicated slightly higher recoveries. Nondigested RNA did not dissolve sufficiently to permit the effective use in concen-rations greater than about 5%.) Experiments were conducted utilizing commercial ources of purines in high concentrations (mertaste*, etc.).

The growth inhibitory effects of the hardener decreased slowly with time. Thus plastic which has been polymerized several weeks has considerably less growth nhibition present than a sample recently formed. Incubation of either the hardener lone or the extracts obtained from pulverized solid with mertase (a mixture of urines) was slightly more effective than the use of RNA alone. RNA-beef extract as slightly superior to mertase alone. The best of this combination includes 80% ertase, 1% RNA, and 5% beef extract. We have determined that the optimum pH of ecovery with this mixture appears to be in the region of 7.5. The recovery of pores embedded in Epon or Ecco-coat is best carried out at 5°C. It appears likely at at temperatures which allow microorganisms to metabolize during the exposure liquid phase, lower recovery values result.

EACHING

We conducted experiments to determine the most effective conditions for aching toxic substances from plastic materials. The methods of leaching studied clude water, buffered solutions at various pH's, selected nonaqueous solvents, d selected azeotropic mixtures of solvents and water. The effect of temperature s also studied. Leaching may be less effective at low temperatures; however, at w temperatures, there is less interaction between the toxic substance and the ganism. It appears that while the organism is still partially or completely cased within the spore wall, leaching may be more effectively carried out; ereas, if the organism is in the process of germination, the microorganism is ch more susceptible to the inhibitors present.

The removal of the toxic materials can be achieved more effectively with rtain solvents; however, the solvents themselves interfere with the growth of the getative organism. It would be necessary to utilize a membrane filtration step to parate the leached material including the microorganisms from the nonaqueous lvents.

The studies conducted with aqueous solutions indicate that spores may be naged in pulverized solids by prolonged exposure at pH2. At ph3, and above, re is no detectable viability if the temperature of the solution is maintained at C or below. Ecco-coat and Epon hardeners were found to be only partially ractable at specific pH's. However, the inhibitors present were slowly destroyed these pH's. As much as 60% of the B. subtilis spores exposed to Epon or Ecco-t hardeners at 0.1% concentration could be recovered following 2 hr of exposure pH2 and, thereafter, readjustment of the pH to 7. Attempts to utilize these data the recovery from solid Ecco-coat or Epon have been disappointing. It appears t either the exposed microorganisms were irreversibly injured in the initial osure to the hardener or that following the neutralization steps, additional inhibi- leached from the solid phase particles produced further growth inhibition. Recent eriments would tend to support both phenomena as contributing to the poor overy from the solid material. We have extracted solid phase Epon with a iety of nonaqueous solvents and selected azeotropic mixtures of solvents and er. Those that are under current study include halogenated hydrocarbon, tone, chloroform and tetrahydroflurane.

DEVELOPMENT OF CULTURE MEDIA

Culture media previously developed in this laboratory support the growth of vegetative organisms thus far studied and promote the germination of spores normally resistant to germination in conventional media.

This medium has served as a starting point in the development of recovery media for the assay of the internal regions of solids. We are conducting a detaile study to determine the efficacy of adding neutralizer constituents to this medium.

In addition to this we are studying the effectiveness of dormancy terminatin substances present in the growth media. The chemical breaking of dormancy ma provide a means of recovering spores that would otherwise be refractory to recov without applying some method for terminating dormancy. We are attempting to de growth media which will support the growth of vegetative cells in the presence of dormancy terminating compounds.

In addition to dormancy, another phenomenon which commonly decreases th recovery of environmental organisms is stalling . We have observed in several instances vegetative nonspore-forming organisms growing out at the third week a later. The presence of purines, pyrimidines, and trace quantities of the yeast extract increases their outgrowth. In resistors and capacitors, organisms incluc spore formers appear to show losses of the capacity to synthesize certain of the cofactors discussed above.

In the development of media containing neutralizers for epoxy compounds, have observed with certain vegetative organisms decreased rates of growth. In comparing the total numbers of colonies, however, we have found that there may certain tradeoffs that must be made to provide nutritional adequacy, optimum neu tralization, and maximum rate of growth.

RECOVERY OF MICROORGANISMS FROM THE INTERIOR OF SOLIDS

The recovery of microorganisms from solids using the best current methodology developed in this program is presented in Table 1. These results, course, do not represent a final level of either sensitivity or precision of the as

The recovery of organisms from Stycast is vastly improved over previous efforts. In the first study of this type of plastic by Dynamic Science Corporatio and others, no recovery at inoculum levels in excess of 10^6 organisms/ml was reported.

The recoveries of paraplast and parlodion were of a high order of magnitu since they are nontoxic.

Table 1. Recovery of microorganisms from solids[a]

Solid material	Recovery, % (10^2 organisms/gm inoculated solid)
Eccocoat 1C2	2
Epon 901	4
Paraplast	78
Parlodion	51
Stycast 1090	32
Maraset	38

[a]Based on 4 trials, 5 replicates each

PUBLICATION DURING FY 1966

Papers Presented at Meetings and Symposia

McNall,* Earl, and Iandolo, J. J., "Microbiological Techniques for Recovery from Interiors of Solids," presented at First National Conference on Spacecraft Sterilization, Pasadena, California, November 1965.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

*Dynamic Science Corporation, Monrovia, Calif.

AUTOMATED MONITORING OF MICROBIAL CONTAMINATION
NASA Work Unit 189-58-23-01-55
JPL 386-82501-2-2945
J. J. McDade

Several installations (Fort Detrick, Frederick, Maryland, University of alifornia, Berkeley, California, and the Douglas Aircraft Company, Santa Monica, alifornia) have been visited to discuss application of biological warfare sampling evices to the reference task. The biological warfare devices do not appear to be pplicable, even with modification(s). Dr. Glaser, at the University of California s a system that may, in part, be applicable to this task. Liaison has been mainined with Glaser.

A recent discussion with J. Savinski of the Sandia Corporation, Albuquerque, w Mexico, indicated that this group was developing a sampling device for estiating the total particulate contamination on surfaces. The method would require nsiderable development and only then might possibly be adapted to sample microl contamination on surfaces. Savinski agreed to keep J. J. McDade informed on status and progress of their work. No other new work has been done on this task.

BLICATIONS DURING FY 1966

None.

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

STERILIZATION SUPPORTING ACTIVITIES

NASA Work Unit 189-58-23-02-55
JPL 386-81101-2-2945

A. S. Irons
J. J. McDade

BJECTIVES

The objective of this task is to maintain in-house microbiological capability to ›pe with the many problems that are unique to spacecraft sterilization.

TRODUCTION

In order to cope with the microbiological problems unique to space hardware erilization it has been necessary to operate our own sterilization laboratory. Its imary function is in support of all microbiological tasks which JPL may find necesry to perform, such as effecting required improvements in microbiological samng and monitoring procedures and the direct support of all Voyager microbiological ›ks which includes the operation of the EASL and SADL facilities.

It is of prime importance that we continue the existing microbiological npetency in support of the sterilization program.

Two general types of support have been provided in the past: (1) Assistance in writing of NASA documents such as "Interim Requirements for Bioclean Facilis" and "Procedures for the Microbiological Examination of Space Hardware," and Management of the JPL Sterilization Group Microbiological Laboratory. Micrological activities conducted in this laboratory have included:

1. Support of the Hughes' Aircraft Co. Surveyor Facility during FY 1965 and FY 1966 furnished valuable data relative to environmental microbiology which will be used in planned FY 1967 studies.

2. Support of all microbiological activities conducted during the construction, check-out, and subsequent operation of the Experimental Assembly and Sterilization Laboratory. This included air sampling, biological assay of components fabricated in the facility versus components fabricated in a "clean" area of Building 18 and visual assay of operations during fabrication of components.

3. Microbial isolates recovered from space hardware, assembly and test facilities and personnel within the facilities are in the process of being identified according to species. These are being sent to three independent laboratories for verification of identification. These isolates will also be evaluated as to their dry heat resistance under conditions stipulated by NASA.

4. Activities and procedures are being constantly updated to correspond to the requirements imposed by the R & D program. As new tasks are generated the backup procedures and techniques needed must be changed to fit into the new programs. In-house activities are increasing; this is placing a greater burden on Sterilization

personnel and facilities. For example: The Sterilization Labora has more recently been involved in the following activities:

a. EASL Phase II - Our work in this area has included air sampling, bio-assay of surfaces, and microbiological suppor concerned with preparation of solutions, sterilization of tool supplies, and parts, preparation of media and visual assay o the EASL facility while under operation.

b. Molesink Studies - Work in this area so far has been aimed a developing and standardizing the experimental techniques to l used in the study. This type of effort is one of the reasons f the existence of the Sterilization Laboratory.

Molesink consists of a high vacuum chamber surrounded by a finned molecular trap. Preliminary work has consisted of inoculating a ladder configuration of stainless steel strip wit spores and subjecting them to a high vacuum (10^{-10} torr) in molesink. The ladder is heated to between 120 to 125°F whi the chamber walls are cooled to approximately -290°F.

c. Support of personnel conducting in-house studies - as an example: Dr. Iandolo who has been conducting "D" value studies on spores as previously discussed, and Dr. McDade who has been conducting extensive in-house investigations concerned with the microbiological assaying of space hardware and the environments in which space hardware is assembled. The generation and compilation of the data he has assembled was made possible because of the existence of the Sterilization Laboratory, which includes the physical structure and the personnel operating the facility.

Studies are also being conducted within EASL in the following areas: Die a of environmental organisms found within the EASL facility; situations that defeat laminar flow systems and comparative settling and recovery experiments using g filters instead of stainless steep strips. Within the laboratory proper we are actively working on culturing, harvesting, preparing, and cleaning spore crops f spore formers found in spacecraft assembly areas; preliminary pure culture pre rations of environmental isolates and preparation of the cultures for "out-of-hou identification and preparation of simulated spacecraft materials to be used for settling experiments.

J. J. McDade completed preparation of the final draft of the revised versi of the NASA, "Procedures for the Microbiological Examination of Space Hardwa The document has been coordinated with J. Ingles and 300 copies of this docume have been sent to NASA Headquarters, Washington, D. C.

J. J. McDade attended and presented a briefing on microbiological monito to the NASA Spacecraft Sterilization Advisory Committee, April 14-17, 1966. T briefing appeared to be well received and stimulated a great deal of interest and discussion of the results obtained during:

1. The JPL/Hughes Surveyor Study.
2. The JPL/Mariner SAF Study.
3. The JPL/Douglas Clean Room Study.
4. The EASL Study.

FUTURE ACTIVITIES

In addition to the previously described tasks it will be necessary to continue procuring equipment, materials, culture media, reagents, contract laboratory technicians, equipment maintenance, up-dating of facilities, and additional support of preparation of NASA documents and attendance at NASA Sterilization Advisory Committee Meetings as required.

PUBLICATIONS DURING FY 1966

Papers Presented at Meetings and Symposia

McDade, J. J., Paik, W. W., Christensen, M., Control of Microbial Contamination: "The Clean Room Concept," Presented at American Public Health Association, Chicago, Ill., October 1965 (will be published soon in Journal of American Public Health).

McDade, J. J., Favero, M. S., and Michaelsen, G. S., "Environmental Microbiology and the Control of Microbial Contamination," Presented at First National Conference on Spacecraft Sterilization, Pasadena, California, November 1965 (in Government Printing Office - to be released soon).

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

(See Publications During FY 1964 above)

EASL/SADL TEST AND OPERATIONS

NASA Work Unit 189-58-23-04-55
JPL 386-80501-2-2930
G. H. Redmann

BJECTIVE

The objective of this unit is to study the requirements for, and develop ethodology and documentation describing, the techniques, procedures, equipment, d facilities necessary to assemble, assay, and certify a capsule system that will tisfy the planetary quarantine requirements.

This effort will utilize a System Task Type Contractor to develop methodology d documentation described in the objective. JPL will furnish the Experimental sembly Sterilization Laboratory (EASL) which presently exists for the contractor's ly orientation and training. Upon completion of the Sterilization Assembly Devel- ment Laboratory (SADL) now under construction at JPL, the contractor's efforts l be centered in this facility.

TIVITIES DURING THIS PERIOD

This work unit was formally proposed to NASA Headquarters on April 15, 1966, approved by NASA on June 15. Since that time a work statement has been written the System Task Type Contractor who will operate these facilities and develop procedures. A Request for Proposal was issued and bids are now being evaluated elect the Contractor.

BLICATIONS DURING FY 1966

ers Presented at Meetings and Symposia

k, W. W., Christensen, M., and McDade, J. J., "Survival of Surface Exposed roorganisms in Spacecraft Assembly Areas," presented at American Society of robiology, Los Angeles, California, May 1966 (will be published in Bacteriologi- Proceedings).

k, W. W., Christensen, M., and McDade, J. J., "Microbiological Studies Con- ed in the Experimental Assembly and Sterilization Laboratory," presented at erican Association for Contamination Control, Houston, Texas, March 1966 (Pub- ed in American Association for Contamination Control magazine).

SPS Contributions

Dade, J. J., Paik, W., Christensen, M., Drummond, D., and Magistrale, V. J., crobiological Studies Conducted in the Experimental Assembly and Sterilization oratory (EASL)," SPS 37-34, Vol. IV.

LICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

AUTOMATED BIOLOGICAL LABORATORY (189-73)

AUTOMATED BIOLOGICAL LABORATORY
NASA Work Unit 189-73-01-01-55
JPL 360-311XX-2-32XX
B. D. Martin
H. W. Ford

JECTIVE

The long-range objective of this task is to conceive, design, and develop an egrated science payload which will be delivered to the surface of Mars by the ager Capsule delivery system and which will be capable of establishing the state iological evolution of that planet. This will, of necessity, be an evolutionary pro-m conducted in a limited number of steps to be defined as a function of the scien- objectives, constraints imposed by the Voyager Project, resource availability, other external factors. It is planned that this effort will be established as a or R&D project, conducted according to NPD 7121.1, and will merge with and ome a part of the Voyager Project at an appropriate future date. Considerable stance will be sought from Ames Research Center, Caltech, and other organiza-s where appropriate.

RT-RANGE OBJECTIVES

The shorter range objectives are as follows:

1. To conduct an Automated Biological Laboratory (ABL) study which will establish a scientific strategy for the biological explorations of Mars, a logical sequence of Voyager-related missions which will accomplish the scientific objectives, and a definition of the evolutionary series of landed science systems which implement the mission objectives. Figure 1 depicts the functional relationship of these objectives with relevant external factors.

2. To prepare a preliminary Project Proposal based upon the study results, to coordinate this proposal with Ames Research Center and the Voyager Project, and to formally submit it to the NASA Headquarters Bioscience Programs there for approval.

3. To identify and pursue the development of new technology required in order to implement the landed science systems defined by the Study.

GRESS

An internal ABL Study plan was prepared and discussed with the NASA Bio-ice Programs Office at JPL in early March. A Research and Technology Resume prepared, submitted to NASA Headquarters, and approved about April 1, 1966. out this time, a Project Manager for ABL was appointed in the JPL Office of arch and Advanced Development, which will have organizational responsibility ie effort until such time as it merges formally with the Voyager Project.

The following specific discussion of progress during the report period is in th context of the previously identified short-term objectives.

During the fourth quarter of FY 1966 several activities basic to the planned ABL study were performed.

Existing documents relevant to establishing the scientific objectives for the ABL program were reviewed. These documents consisted of:

1. The NAS-NRC Summer Study Report, Publication 1296.
2. Aeronutronics ABL study reports, Aeronutronics Publication U-3
3. Woods Hole study reports, NAS-NRC, December 1965.
4. Publications of Ames Research Laboratory.
5. Report of Ad Hoc Working Group, Newport Beach, 1965.
6. JPL - Minimum Biological Payload (Preliminary Report), 1964.
7. Westex Committee Reports (1958-1960).
8. AVCO Voyager study reports.
9. Mariner 1969 Capsule Report (JPL EPD-261, December 1964).
10. Various reports about observations of Mars.

In addition, several methods of approach to planning for the biological exploration of Mars were examined in cooperation with the participating sections an advisory panel from the Caltech biology, astronomy, and geology staffs.

1. The use of various strategies was examined for their value in pl ning the program.
2. The use of mission simulation was also examined.
3. The use of hypotheses about life on Mars was examined in some detail.

At present it appears that each of the above methods of approach may very have its place; however, the examination of various hypotheses appeared to be o most immediate value for early stages of the study.

On the basis of the above review and individual studies, recommendations scientific objectives for the biological exploration of Mars, including future ABL Voyager missions, are being formulated.

A library of subject matter pertinent to all phases of an ABL study is bein prepared. The intent of this library is to provide a central, easily accessible s of relevant material to the JPL staff assigned to ABL, and to facilitate the orien of specialists from outside JPL who will be working on the project.

As part of developing an ABL program, inputs are being provided to the Voyager Project on possible mission objectives for different Voyager flyby orbiter and lander configurations. Current plans are to continue the present activities, and to involve ARC to an increasing degree as the study effort progresses.

Preparation of the preliminary Project Proposal was begun late in the report period. As a first step in establishing a coordinated effort with Ames Research Center, Dr. Young of ARC attended the JPL Bioscience program review and a number of JPL personnel were present at the ARC review in April. The ABL Project Manager has been participating in relevant aspects of the Voyager Project Mission Studies.

A preliminary study of pacing new technology requirements has been conducted. Although there are a large number of such requirements, manpower limitations during the report period have permitted the initiation of only one effort, in the area of sample acquisition and transport.

The objective of this program is the development of prototype sample acquisition and handling systems capable of supplying small uncontaminated and unaltered particulate samples to instruments employed in Voyager biological capsule configurations.

Past efforts in biological sampling at JPL and by Litton Systems under JPL contract have concentrated upon aerosolization and pneumatic transport of the sample. A NASA Headquarters' funded contract with Aeronutronic Division of the Philco Corporation, NASw-1065, Modification No. 2, a follow-on sampling effort to their ABL study, is being technically monitored by JPL under this effort. It is the intent of this contract to do a conceptual design study of possible simple (precursor ABL) capsule-borne samplers employing means of sampling other than pneumatic to determine whether any other methods might be more promising. Technical direction of this contract has comprised the bulk of the effort on this program. The end result of this contract will be two engineering prototype samplers, one which deploys radially (vertically) from the capsule and the other which deploys a moderate distance (about ft) from the capsule.

A Statement of Work was prepared calling for a 45-day conceptual design study of two basic types of particulate samplers in the 3-lb weight range capable of withstanding high landing shock loads. The first type of sampler, which was to deploy essentially vertically into the soil directly under the capsule, would obtain a subsurface sample from a very limited area, whereas the second type, which deploys horizontally, would take a surface sample from a larger area. Constraints imposed by the Statement of Work served to direct the effort to simpler pre-ABL type samplers than most of those proposed in the Aeronutronic ABL study.

At the conceptual design review, held at JPL on March 22, some 32 concepts were presented, from which eight were selected for further study. On April 4, these concepts along with in-house geosampling devices under development were presented to members of the Voyager capsule design team. Subsequently, the number of concepts was narrowed to four and finally to two, shown as Fig. 2 and 3.

Figure 2 shows the vertically deployed abrading sieve cone (originated in the JPL Geosampling SRT Work Unit 185-37-20-14-55) which rotates as it slowly descends to the ground. It will admit only particles of sizes smaller than the entry holes

(set by the maximum size particle the experiments can handle); it can comminute and scrape material too large to enter the holes, such as clods or hardpan; and it can abrade rock surfaces to a limited extent. The horizontally deployed sampler, shown in Fig. 3, is a heavier, more complex device of a greater capability. It is a sweeper abrader on the end of a telescoping boom capable of being repeatedly extended and retracted and of being rotated in azimuth and elevation. It is thus capable of sweepin samples from a sector of appreciable surface area.

It is hoped that these prototype samplers together with the Litton aerosol sampler will provide bases of comparison from which trade-off information may be derived. It is expected that the samplers delivered to JPL by Aeronutronic on this contract will be tested at JPL with simulated Martian soil conditions and in a 5-mb atmosphere.

It is expected that additional new technology requirements will be pursued as resources permit.

PUBLICATIONS DURING FY 1966

None.

PUBLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None.

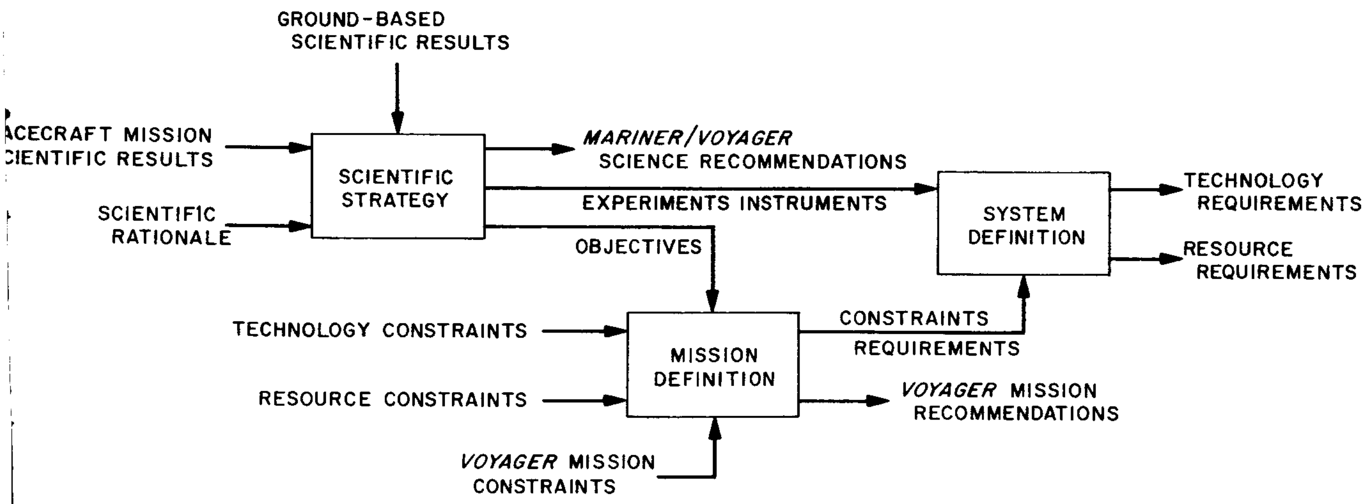

Fig. 1. ABL study functional relationships

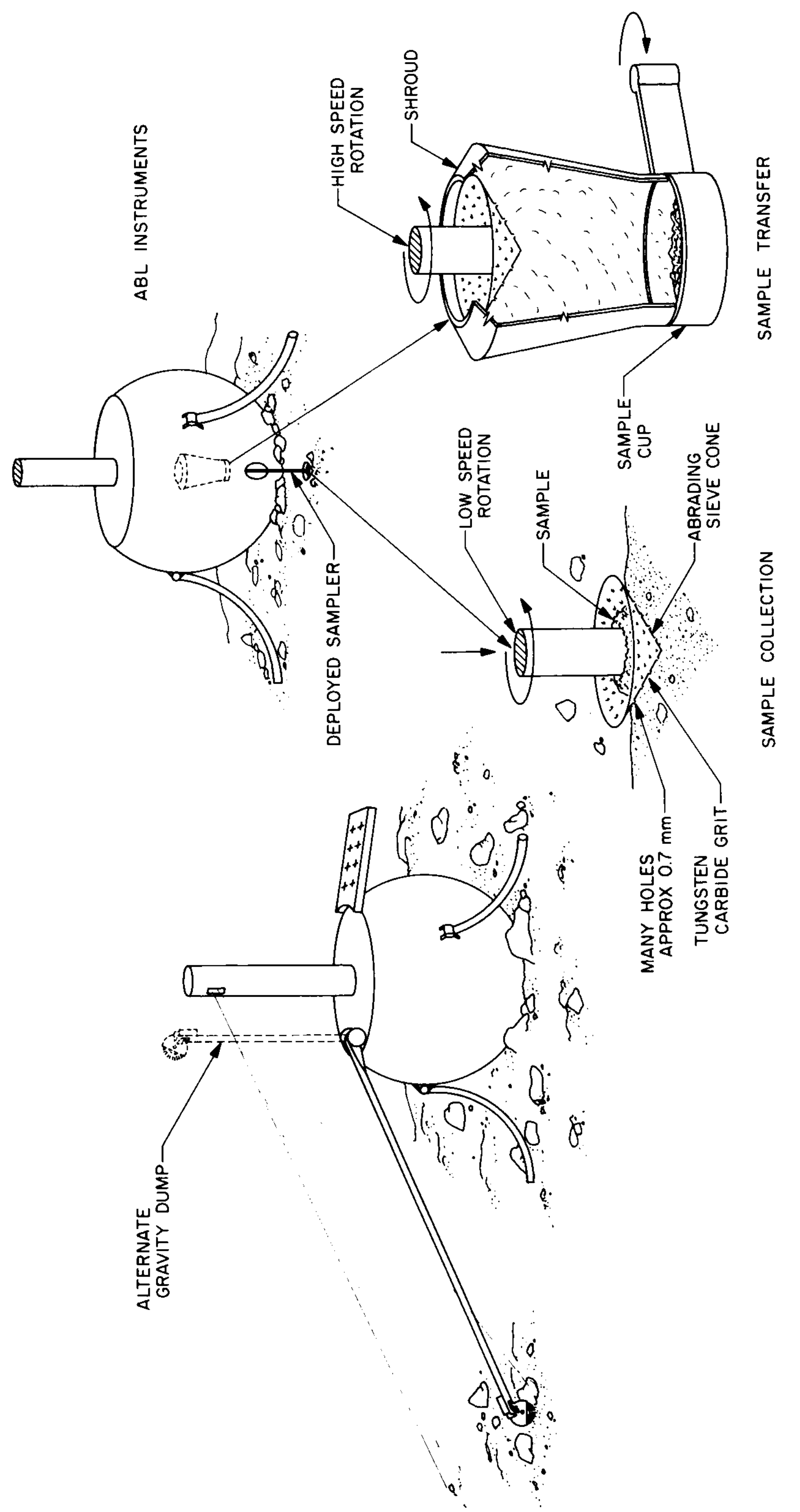

Fig. 2. Vertically deployed abrading sieve

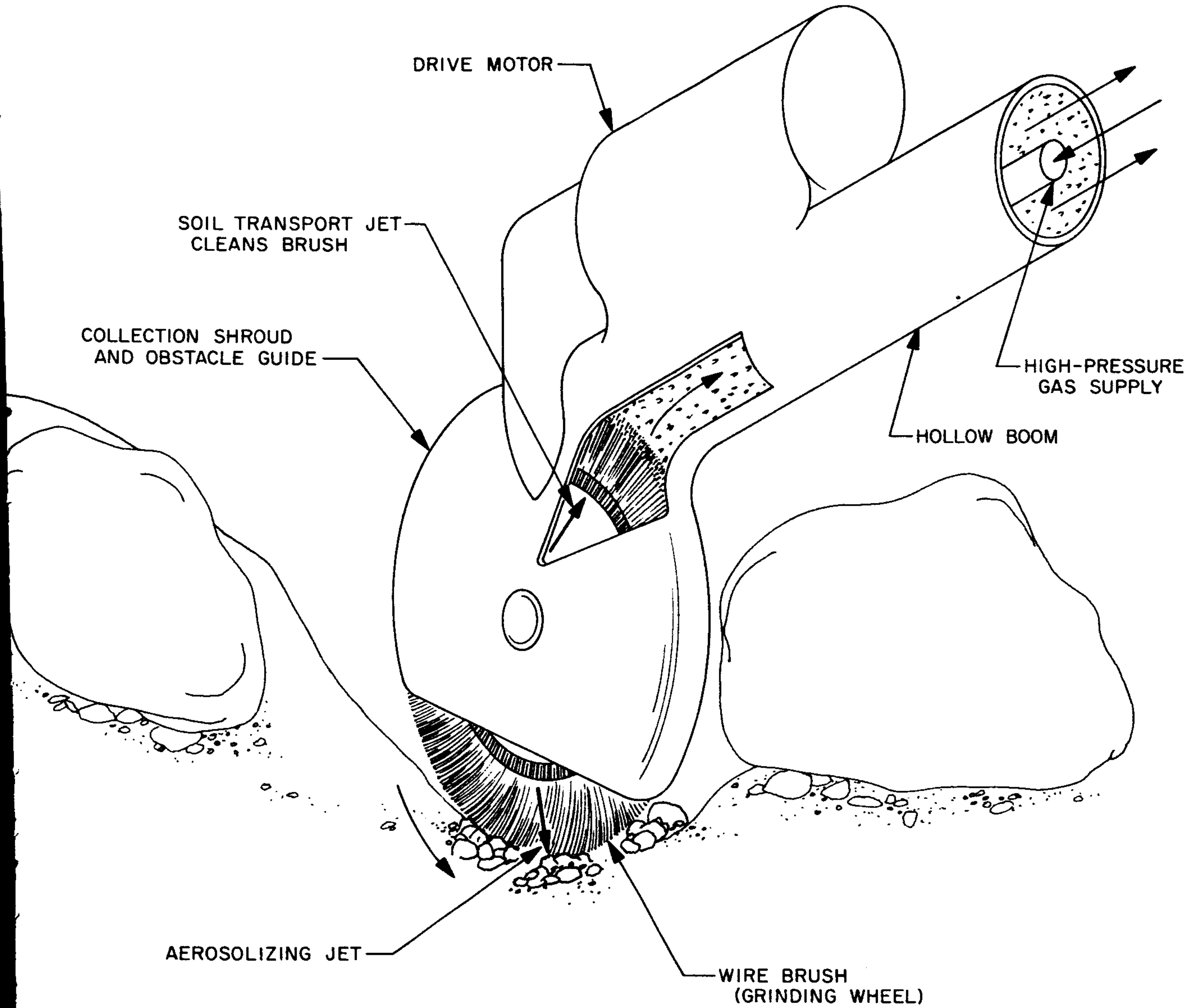

Fig. 3. Horizontally deployed sampler

Part D
Manned Space Sciences

MANNED SPACE SCIENCES (190)

PLANETOLOGY (190-42)
SPECTRAL PHOTOGRAPHY
NASA Work Unit 190-42-03-01-55
JPL 390-10101-2-3250

(This work unit is jointly funded under NASA Code 185-42-20-27-55. Refer to e Lunar and Planetary Exploration Section for the appropriate report.)

LUNAR AND PLANETARY X-RAY DIFFRACTION PROGRAM

NASA Work Unit 190-42-03-02-55

JPL 390-20401-2-3250

(This work unit is jointly funded under NASA Code 185-37-20-02-55. Refer to the Lunar and Planetary Exploration Section for the appropriate report.)

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GAMMA RAY SPECTROSCOPY
NASA Work Unit 190-42-19-01-55
JPL 390-20501-2-3250

A. E. Metzger

(This work unit is jointly funded under NASA Code 185-37-20-13-55. Refer to ıe Lunar and Planetary Exploration Section for the appropriate report.)

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AIRBORNE MICROWAVE RADIOMETRY

NASA Work Unit 190-42-20-16-55
JPL 390-20301-1-3250
F. T. Barath

)BJECTIVE

This work unit is part of the Passive Microwave Feasibility Study Program irected by the NASA Space Applications Programs Office. The objectives are: 1) to provide passive microwave instrumentation for aircraft use, and to perform xtensive measurements with it, and (2) to coordinate the Passive Microwave Team ctivities.

ROGRESS

In the first area, the two dual-channel microwave radiometers aboard the ASA-MSC Convair 240A aircraft, were operated during four missions as follows:) Argus Island, Bermuda, and Gulf Stream, for oceanography (March), (2) Goose ay, Labrador, for iceberg studies (April), (3) Ashville, N. C., for agricultural udies (May), and (4) Weslaco, Fla., for oceanography and hydrology (May). These ere all multi-sensor flights (IR, optical, etc., included) and yielded considerable nounts of raw data. The data from this, as well as earlier missions, are still ing processed at MSC for eventual study at JPL, MIT, OSU and other interested nters. The measurement program and data analysis will continue throughout the xt year.

An advanced imager has been completed by North American Aviation and will installed aboard the NASA-MSC P3A aircraft when the aircraft becomes available. e imager will yield stereoscopic views of selected test sites and will be flown oughout next year. Specifications for advanced spectral radiometers have been epared. These will be procured by MSC and also installed aboard the P3A aircraft.

A ground-based backup and calibration measurement program contract with ytheon has been in full operation after resolution of instrumental difficulties. Four es have been measured to date and good preliminary data obtained. This program l be extended as long as the FY 1967 funding will permit (approximately 3 mo).

In the second area, considerable effort has been expended and will be expended coordinating the various laboratory, field, and flight activities of a large number participating and interested organizations. Two full-fledged coordination meetings re held, one in Washington, D. C. (March 15-16, 1966) and one in Columbus, Ohio ne 14-15, 1966).

BLICATIONS DURING FY 1966

None

BLICATIONS ANTICIPATED DURING NEXT REPORT PERIOD

None

INFRARED THERMAL EMISSION FROM SILICATES
NASA Work Unit 190-42-20-20-55
JPL 390-20101-2-3250

(This work unit is jointly funded under NASA Code 185-42-20-20-55. Refer to e Lunar and Planetary Exploration Section for the appropriate report.)